OVERSIGHT REVIEW OF RESEARCH LABORATORY PROGRAMS AT THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

Y 4. SCI 2: 104/43

Oversight Review of Research Labora...

HEARING

BEFORE THE

SUBCOMMITTEE ON TECHNOLOGY

OF THE

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTH CONGRESS

SECOND SESSION

MAY 2, 1996

[No. 43]

Printed for the use of the Committee on Science

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CONTENTS

WITNESSES

Page

May 2, 1996:
- Dr. Katharine Gebbie, Director, Physics Laboratory, National Institute of Standards and Technology 4
- Dr. C. Kumar Patel, Vice Chancellor, Research Office, University of California 11
- Dr. Buhdatt Paliwal, Professor of Human Oncology, University of Wisconsin 25
- Dr. Hratch Semerjian, Director, Chemical Science and Technology Laboratory, National Institute of Standards and Technology 45
- Dr. Isiah Warner, Chair, National Research Council Board on Assessment of NIST Programs Panel for Chemical Science and Technology 62
- Dr. Rita Colwell, President, University of Maryland Biotechnology Institute, University of Maryland 92

APPENDIX

Statement submitted for the record by the American College of Radiology 105

OVERSIGHT REVIEW OF RESEARCH LABORATORY PROGRAMS AT THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

THURSDAY, MAY 2, 1996

U.S. House of Representatives,
Committee on Science,
Subcommittee on Technology,
Washington, DC.

The Subcommittee met at 10:05 a.m. in Room 2325 of the Rayburn House Office Building, the Honorable Constance A. Morella, Chairwoman of the Subcommittee, presiding.

Mrs. Morella. I am going to call the Technology Subcommittee to order and welcome all of you who are here today.

As we have said many times before, the work of the National Institute of Standards and Technology in standards, metrology, and technology development is vital to our Nation's competitiveness.

However, these contributions often go unnoticed or are difficult to identify due to the unique behind-the-scenes role that NIST plays as a technology enabler, consensus standards builder, and industry facilitator.

So in recognition of this dilemma, Congressman Tanner referred to NIST as the "stealth agency" at our recent authorization hearing. I have always said it is the best-kept secret.

Hopefully the hearing we are having today will make NIST's role in enhancing the Nation's competitiveness economically and in other ways more prominent on Congress' radar screen!

The occasion of these hearings is particularly timely due to the growing importance of technology in our society. In particular, the NIST role in this technology revolution is also changing.

Federal institutions are being asked to do more with less and become more responsive to their customers, including those in industry.

Further, once competing industrial firms are downsizing their corporate research laboratories and increasingly forming alliances—often in partnership with NIST—to meet the demands of global competition. So the linkages between science, technology, and innovation are becoming more complex.

The road to commercial success is more fast-paced and market driven. As a result, these industrial alliances often develop roadmaps as a vehicle to identify and solve industry-wide technical barriers. These issues and the NIST response to this changing environment will be explored in these hearings.

During the course of these hearings, we are honored to have as witnesses the directors of four of the NIST intramural laboratories that are at the forefront of this revolution.

Today we will discuss two of these labs: the Physics Laboratory, and the Chemical Sciences and Technology Laboratory.

So we are fortunate that the National Research Council performs an annual detailed assessment of the intramural NIST Laboratory Programs carried out by almost 150 scientists and engineers from academia, industry, and other research laboratories.

We are going to hear from the Chairs of the Panels assessing these NIST Laboratories. Also, we are pleased to have several of NIST's important customers in industry and academia give their perspectives on the value of the NIST activities.

I look forward to the testimony of the witnesses, and want you to know also that we feel that by having these hearings we will have important information permanently put into our records.

So I would like to now recognize the fact that we have the Ranking Member of the Full Science Committee with us today, George Brown.

Thank you for being here. You didn't have an opening statement, did you?

Mr. BROWN. I do not have a prepared statement, but if the Chair would be kind enough to indulge me I would like to make just a brief remark or two.

Mrs. MORELLA. Indeed.

Mr. BROWN. First I want to thank you for holding these hearings. Indeed, NIST has been somewhat of a "stealth" agency in terms of the attention devoted to it by the Congress.

I must say that this is probably a compliment to the fact that it does not require as much as Congressional oversight because it has such an excellent system of its own for securing the very best scientific oversight, which is a tribute to it.

I would like to also say that for those who may feel that there is not an appropriate role in science and technology for the Federal Government, this agency demonstrates that there is indeed an extremely important role.

I might warn the Gentlelady that this is an agency, or an operation that Mr. Calvert and I might want to steal for California, if you are not careful, and Ms. Lofgren, also. We do have three Californians here, don't we? Well, this is the time for a coup, isn't it?

[Laughter.]

Mr. BROWN. But I do appreciate this hearing, and I am very happy to play a role in making sure that NIST does get more credit for the fine work that it does.

Thank you, Madam Chairwoman.

Mrs. MORELLA. Thank you, Mr. Brown.

It was recently that Senator Byrd from West Virginia spoke very vehemently against the line item veto. And someone said, well, why do you think he did that? And I said, it's because he believes in government on the move—into West Virginia.

[Laughter.]

Mrs. MORELLA. I want you to know that I will do all I can to make sure that NIST is not on the move out of Gaithersburg, Maryland, and Boulder, Colorado.

I would now like to turn to Ms. Lofgren who is surrogate ranking member of the Subcommittee.

Ms. LOFGREN. Thank you, Chairwoman Morella.

I join you in welcoming our witnesses today. During the 104th Congress, I think most of our Congressional attention has been extended to the external programs of NIST—the ATP Program, MEP Program—and we have not given much attention to the Lab programs.

I think many members of the public, and I would include many members of Congress, really do not know what NIST labs do. I think this hearing will help remove the stealth nature from the agency.

I think it is worth noting that it has not always been the case that measurements have been obscured. The importance of standards and measurements would not have been lost on the framers of our Constitution.

In the 18th Century they specified in the Constitution the governmental role of creating and maintaining standards of measurement—standards of weights and measures, to be precise—as one of the critical functions of the Federal Government.

It is one of the few specific functions that is lined out in the government. Now of course they were thinking how could a citizen know that an ounce of gold would be the same in Maryland as it was in Massachusetts, and I doubt very much that they could have envisioned the march of technology and modern commerce that has made the task of NIST quite different today than it was when the Constitution was drafted.

But NIST of course has evolved to meet the new challenges.

I think this is an important hearing because, as we all know, later this year it is likely that a bill to dismantle the Commerce Department will come to the Floor. Earlier versions of this legislation—and to my knowledge current versions—provide that NIST would either be privatized or would be reduced by 25 percent in funding below last year's fiscal level.

I am hoping that the witnesses can address what effect that proposal would have on your mission, and what effect those proposals would have on American commerce and the safety of American consumers as well as our productivity in industry and our competitive edge in the international market.

With that, I look forward to hearing from the witnesses, and I thank the Chairwoman for her wisdom in calling them.

Mrs. MORELLA. Thank you, Ms. Lofgren.

I would now like to recognize the Vice Chair of the Subcommittee, Ken Calvert, who has been a very loyal and distinguished believer in NIST.

Mr. Calvert?

Mr. CALVERT. Thank you, Madam Chairwoman.

I wish to express my appreciation to you for holding this hearing this morning. With the University of California-Riverside right in the heart of my District which I represent, and which the former-Chairman Brown represented for many years, I know we both appreciate the importance of research in the fields of physics, chemistry, and computers and how well it would fit in right there next to the University of California.

[Laughter.]

Mr. CALVERT. But I know it is represented very well by the young lady from Maryland, and she won't let it go, so we probably cannot have it, George.

It will be interesting for me personally, as a former businessman, to know how NIST and its various Laboratories have succeeded in cooperating with the private sector in giving American industry a competitive advantage in the world marketplace.

I wish to convey my thanks and appreciation to Drs. Gebbie, Patel, Paliwal, Semerjian, Warner, and Colwell—this is a test; if I can pass this, I can get through the rest of the hearing——

[Laughter.]

Mr. CALVERT. (continuing) —for taking some of their valuable time to be with us today.

Again, Madam Chairwoman, thank you for having this hearing and I look forward to your testimony.

Mrs. MORELLA. Thanks, Mr. Calvert.

I also want to thank the panelists. We are going to have our first panel, and I am going to recognize in this order Dr. Katharine Gebbie, who is Director of the Physics Laboratory at the National Institute of Standards and Technology.

She will then be followed by Dr. C. Kumar Patel, who is the Vice Chancellor of the Research Office of the University of California.

To then be followed by Dr. Buhdatt Paliwal, who is Professor of Human Oncology at the University of Wisconsin.

We traditionally have given our speakers five minutes. We can go a little over that, but we are going to try to keep you to five minutes and then respond to any questions that we may have.

I do want you to know also that your testimonies in their entirety will be part of the record.

So, Dr. Gebbie.

STATEMENT OF DR. KATHARINE GEBBIE, DIRECTOR, PHYSICS LABORATORY, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

Dr. GEBBIE. Madam Chairwoman and Members of the Subcommittee:

I welcome this opportunity to tell you about some of the work in the Physics Laboratory at the National Institute of Standards and Technology.

You have my written testimony. This morning I just want to make one or two points. Physics is at the heart of what is the very core of all physical measurements and standards, voltage, length, time, frequency, temperature, the measurements and standards that the United States mandates to be a Federal responsibility.

Consistent with this mandate, the Physics Laboratory supports U.S. industry, government, and the scientific community by providing measurement services and support and research for the electronics, optical, and radiation technologies.

Science and technology, once considered separate and sequential, are now becoming increasingly coupled. The Physics Laboratory's work, therefore, spans the whole range from tests of the most fundamental postulates of physics to services that respond to the immediate needs of industry for measurements and standards.

To give you a feel for what I am talking about, I would like to use one example. The Physics Laboratory has the responsibility for maintaining and disseminating the Nation's standards for time and frequency.

To respond to the immediate needs of the public and industry, we have three radio stations that provide time and frequency signals that cover the entire world.

We have an automatic computing time service by which stock and commodity traders and all businesses can automatically have their personal computers set to the correct time every time they log on—and you can do that, too, with your computers.

Then we also provide time transfer services using the Global Positioning System satellites.

Now to back up these services, we have just completed a ten-year state-of-the-art engineering program to develop what is now the world's most accurate atomic beam time standards, which we call NIST-7. This is ten-times more accurate than our previous standard, and puts us back into a position of world leadership which we lost in 1950 shortly after we developed the world's first atomic clock.

This new standard positions us well to address—it has the reliability and stability to address the needs of emerging technologies in telecommunications, electronic networking, navigation, and in science.

Then, to anticipate the future needs of time and frequency measurements, we have a fundamental program in atomic cooling and trapping of atoms and ions. It was in the course of this work that we created for the first time a so-called Bose-Einstein Condensate, a new form of matter that had been predicted 70 years ago by Bose and Einstein but had never been observed before.

This was named the "Molecule of the Year" by *Science Magazine,* and we have brought you a poster, and also behind it a picture, Madam Chairwoman, for your office.

The people involved in this work, one of them is a member of the National Academy of Sciences. His work was mentioned in the 1989 Nobel Prize for Physics. The leader of this current work has already received many national and international awards.

So I have tried, Madam Chairwoman, to give you the feel for just one of our programs, the range of activities that we cover, and the caliber of the scientists who are working on these.

Thank you.

[The prepared statement of Dr. Gebbie follows:]

STATEMENT OF

KATHARINE GEBBIE

DIRECTOR, PHYSICS LABORATORY

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

BEFORE THE

SUBCOMMITTEE ON TECHNOLOGY

COMMITTEE ON SCIENCE

HOUSE OF REPRESENTATIVES

MAY 2, 1996

Madam Chairwoman and Members of the Subcommittee, I welcome this opportunity to discuss with you the work being done in the Physics Laboratory at the National Institute of Standards and Technology (NIST). Physics is, of course, at the very core of all physical standards and measurement, which the United States mandates as a Federal responsibility.

Consistent with this mandate, the Physics Laboratory supports U.S. industry, government and the scientific community by providing measurement services and research for electronic, optical, and radiation technology. Science and technology, once considered separate and sequential, are now becoming increasingly coupled. The work of our Laboratory thus spans the full range from programs that address the fundamental postulates of physics to those that respond to the immediate measurement needs of industry and commerce.

For example, the Physics Laboratory is responsible for maintaining and disseminating the Nation's standards of time and frequency and for coordinating them internationally.

To respond to the Nation's immediate needs, we provide a wide variety of time and frequency services including radio stations that broadcast time signals over most of the world, an Automated Computer Time Service that commodity traders, for example, can use to set the clocks on their personal computers, and a time transfer service using the Global Positioning System (GPS) satellites.

To back up these services, we have just completed an 10-year state-of-the-art engineering project and commissioned NIST-7, the most accurate atomic beam clock in the world. This standard represents a ten-fold advancement over the previous NIST standard. With this new standard, the United States regained a lead position, which it had lost to Europe shortly after the development of the first atomic clock at NBS in 1950. The performance of this clock provides NIST with a reference that is both accurate and stable enough to support rapidly advancing technology in, for example, telecommunications and navigation.

At the same time, we are pursuing research on trapped and cooled atoms aimed at developing the next generation of frequency standards, one thousand times more accurate than NIST-7. In the course of this work, we created a so-called Bose-Einstein condensate, a new state of matter that had been predicted by Bose and Einstein 70 years ago. This condensate was named "Molecular of the Year" by *Science*. One of our scientists, who developed many of the cooling techniques, is a member of the National Academy of Sciences and was mentioned in the writeup of the 1989 Nobel Prize for Physics. The leader of the project has already received national and international recognition for his achievement.

Why do we need a clock with one thousand times more accuracy? We can't necessarily envision all the uses, but what we do know is that for the past 50 years, the accuracy of our frequency standard has increased by a factor of 10 every seven years—and every time it increased, there was a need for it, and U.S. economic competitiveness depended on NIST to provide it. If we had waited until the need arose, we would always have been seven years behind.

Four Thrusts

Coming back to the Laboratory as a whole, we have identified four strategic areas where we believe our experience and distinctive skills best contribute to industrial requirements and critical national needs by providing measurement methods, standards, and data:

- Electronic and magnetic devices—where we develop innovative measurement methods of use to the electronics industry for device characterization and electronic information and communication. For example, we pioneered nanoscale magnetic imaging techniques used by manufacturers of magnetic storage devices seeking to increase the density of stored information.
- Optical technology—where we provide the national basis for optical radiation measurement and develop optical measurement systems for industrial and environmental needs. Our standards are used, for example, by the lighting industry to produce more efficient bulbs and by the photographic industry to assure uniform quality, so that when you buy a Kodak film anywhere in the world, you know it will produce the same color tone as the one you buy in the United States.
- Radiation applications and control—where we support the effective and safe use of radiation for industrial and health applications. We provide standards and measurement quality assurance services. We develop and evaluate new radiation measurement methods, and we provide critical data that allow doctors to predict how much radiation actually reaches a patient's tumor. The results of this work are relied upon, for example, in hospitals where radiation diagnostic and therapy procedures are performed and in U.S. companies where radiation processing is used to manufacture products.
- Fundamental physical quantities—where we improve definitions and realizations of base and derived units and pursue opportunities for new determinations of fundamental physical constants. One effort here is aimed at determining the fundamental properties of silicon sufficiently well to redefine the kilogram in terms of numbers of silicon atoms. Currently, the world's standard of mass is a platinum iridium cylinder in an underground safe in a pavilion outside Paris.

Why NIST?

Those research and development activities upon which the measurement infrastructure of the United States depends are the constitutional responsibility of the Federal government. No other institution—public or private—performs this function for the United States. The industrial sector understands—as did the framers of our Constitution—that this must be a centrally executed responsibility, performed competently and fairly for all industry, one that must not become a competitive pawn of any one element of the private sector.

University programs, funded by NSF for example, cannot adequately support the measurement needs of the United States. Such programs are based on grants to individuals or small groups of investigators motivated, appropriately, by a combination of intellectual challenge, opportunity, and the universities' primary mission to educate future scientists. Only at NIST does the country have the mission oriented, interdisciplinary staff with the scientific weight to address the nation's most challenging measurement problems.

At NIST you will find that the same scientists who are world leaders in the longer-term fundamental research—quantum computing and Bose-Einstein Condensation, for example—are also the most eager to see their efforts amplified by applying their talents to the solution of real-world problems. We believe that the quality of our services stems in large measure from the breadth, vigor and excellence of our research programs, and that our contributions are credible only to the extent that they are based on the best technical judgment available. Thus, the Laboratory addresses the fundamental triad of standards, measurement methods, and data in a climate of vigorous and competitive research.

Examples of Accomplishments

Now I'd like to give you the flavor of some of the accomplishments of the Physics Laboratory.

Fundamental Precision Measurement:

New State of Matter

Our Laboratory was the first to demonstrate Bose-Einstein Condensation, a new form of matter originally predicted to exist by Bose and Einstein in 1924. Last July one of our young scientists cooled an assembly of rubidium atoms to a record low temperature of 10 billionths of a degree, where it condensed into what we call a single quantum state. While this could have—and has since—been done elsewhere, only at NIST is the emphasis on exploiting such a condensate to make a revolutionary new measurement device: an atom laser. An atom laser is the analog of the familiar optical laser and would allow, for example, new gyroscopes 10 billion times more accurate than our current laser gyroscopes.

Electronic and Optical Measurement and Standards:

Microlithography

Physics Laboratory scientists, in collaboration with Harvard University researchers, have demonstrated a new form of microlithography that uses neutral atoms instead of light to write patterns on silicon. The new method offers the promise of allowing integrated circuits or other microfabricated objects to be manufactured about 10 times smaller than is possible with light-based lithography methods.

Imaging Magnetic Bits

We have developed a magnetic microscope for imaging microscopic magnetic domains responsible for the performance of high density information storage devices and high efficiency power transformers. Magnetic domains can be directly imaged with atomic-scale resolution. Magnetic storage is a $30 billion per year industry, and power lost to transformer cores is estimated to be $5 billion/year. This development is the culmination of a research and development project using spin polarized electrons to study the properties of magnetic surfaces.

Atomic Clock

NIST-7, a 7th generation atomic clock developed in the Physics Laboratory at NIST over the last 10 years, has achieved an accuracy of five parts in 10^{15}, or about 0.2 microseconds over a year's time. This clock is the basis for a wide range of time and frequency services provided by NIST. Telecommunications, navigation, stock and commodity trading, electronic networks, radio and television broadcasting, air traffic control and traffic light synchronization are a few of the many commercial activities dependent on these services.

Synchronization Helps Commuters

Los Angeles County, alone, saves an estimated 22 million gallons of gasoline every year and 55,000 hours of driving time each day by synchronizing traffic lights with our time and frequency services.

Clocks for PCs

A widely used service of the Physics Laboratory provides accurate time information in a digital format which can be used to automatically correct the time on standalone PCs, to synchronize time-clocks, and to provide time to financial institutions. The services can be accessed via dial-up telephone lines with modems and the Internet. The information is directly traceable to the primary clock ensemble maintained by the NIST Boulder Laboratories. There are now more than 70,000 time requests per day and they are increasing at the rate of 10 percent per month.

Precision Timing for Telecommunications

We helped telecommunications companies to synchronize their transmissions to provide their users error-free connections. "By my calculation, NIST saved us almost one year in the time it took to develop the proper synchronization standard," says Rodney J. Boehm, chairman of a subcommittee of the telecommunications industry's Exchange Carriers Association. "It is imperative that NIST continues to be involved to help us and ensure that we use NIST expertise to speed up the standards process for the good of the entire industry," Boehm adds.

Navigation with Global Positioning System

The Physics Laboratory played an important supportive role in the creation of the Defense Department's Global Positioning System, a satellite-based navigation network. We provided information on organizing the ground monitoring stations and analyzing time data. Even today, NIST has a contract with the operators of this system to assist in evaluating the performance of the satellites. In particular, NIST developed a method, called the Common View Method, of transmitting time and frequency information with great accuracy. This method is used—and relied upon—by high-end users, such as the Jet Propulsion Laboratory, who need very accurate timing information.

Space Communications

The Deep Space Network, which is used by NASA as its radiotelescope communications link to space flights, such as Atlantis or Apollo 13, requires the high accuracy of NIST-7 for the synchronization of transmissions utilizing the different ground stations.

Measurement and Standards for Diagnostic and Therapeutic Radiology

Mammography

Breast cancer will strike one in eight women in the U.S.A., making it the most common form of cancer among women. Approximately 46,000 women die of the disease each year. Early stage tumors, which can be detected in mammograms, are 90 to 100 percent curable. Recognizing the critical role that x-ray mammography has in early breast cancer detection, and the role of high quality physical measurements in reassuring women about the safety of mammographic procedures, Congress in 1992 passed the Mammography Quality Standards Act. The implementation of this Act has highlighted the need for improved measurement standards at NIST for two radiologic quantities, x-ray kilovoltage and radiation exposure.

Image Quality

Since mammography requires relatively low-energy x-ray beams in order to image calcifications and small tissue abnormalities, small changes in voltage yield significant changes in dose and image quality. In response to an urgent request from the Mammography Committee of the Conference of Radiation Control Program Directors, the Physics Laboratory has developed an entirely new method for measuring the voltage across these x-ray tubes—a method based on our fundamental understanding of the behavior of x-rays, which allows us to measure their energy directly. A research grade portable instrument based on this concept will be available in June; field instruments will be generally available to calibration facilities in about a year. John Boone of the School of Medicine of the University of California, Davis, has called this "a miracle device which lets scientists measure more accurately than ever before important properties of the x-ray beam used in mammography."

Radiation Exposure

The radiation exposures in x-ray mammography must be kept to a minimum consistent with good image quality. The Food and Drug Administration is implementing the Mammography Quality Standards Act by certifying that equipment in U.S. mammography facilities is traceable to national measurement standards for radiation exposure. In response to a request from an industry group (Council on Ionizing Radiation Measurements and Standards), the Physics Laboratory in collaboration with the Center for Devices and Radiological Health at FDA, and the Medical Physics Department at the University of Wisconsin, has recently established new national standards for measuring radiation exposure and new facilities for calibrating exposure meters. The accuracy of all radiation exposure measurements in approximately 11,000 U.S. mammography facilities will trace back to the new NIST standards. You will be hearing more about this facility from Professor Paliwal.

Radiation Therapy

In addition to the x-rays used for diagnosing cancer, high energy beams of photons, electrons, protons and neutrons are used to treat the 600,000 Americans who receive radiation therapy each year. Each of these facilities relies on radiation standards developed in the Physics Laboratory to ensure that the patient receives the correct dose: too little radiation does not kill the cancer; too much kills the patient.

Standards for Prostate Cancer Treatment

Recent studies have shown that prostate cancer patients treated with radiation seed implants are just as likely to be disease free five years after treatment as men who had undergone surgery to remove the cancer—and with many fewer of the unpleasant side effects. NIST is the only laboratory in the world that now offers standards for the iodine-125 isotope used in the most common of these seed implants.

Optical Radiation Measurement and Standards

Looking Good

We provide optical standard reference materials to a broad range of U.S. manufacturers whose sales depend critically on how a product looks to the customer, e.g., automobiles, paints, plastics, clothes, toys, furniture, and packaging materials.

Photographic Film Industry

We work with and provide standards to major photographic film manufacturers to ensure that a given type of film produced in many factories throughout the world is equivalent and of consistently high quality.

Color Displays

Our optical radiation calibration services are used by companies that make and calibrate instruments used in the graphic arts fields, for example, to ensure that computer displays give accurate rendition of color.

Remote Sensing

We provide optical radiation calibration support for high priority, interagency, remote-sensing programs involving national defense, environmental monitoring, and space research. For example, our infrared standards are used in developing heat-seeking missile sensors and aviator night vision goggles. Our ultraviolet standards are used in international efforts to monitor longterm changes in the intensity of terrestrial solar ultraviolet radiation which can occur as a result of ozone layer changes—more than one million cases of skin cancer will occur this year due to exposure to harmful UV rays from the sun. Our vacuum ultraviolet and visible radiation standards were used to characterize and calibrate all the Hubble space telescope cameras.

Setting Priorities

With such a variety of measurement skills and needs, how do we decide which ones are appropriate and possible for us to take on? In each of our areas, we have different—but long established—methods for setting priorities and measuring results. All of these methods focus on understanding the needs of our customers.

In the area of optical radiation technology, we look to the Council for Optical Radiation Measurements (CORM). NIST established CORM in 1972 to determine Pressing Problems and Projected National Needs in Optical Radiation Measurement. CORM is a nonprofit organization composed of individual members from industry, government and academe interested in the measurement of optical radiation. About 150 U.S. companies are represented by CORM. CORM's aim is to establish a consensus among interested parties on industrial and academic requirements for physical standards, calibration services, and interlaboratory collaboration programs in the field of optical radiation measurements. This includes setting priorities, liaison with NIST, dissemination of information, response to inquiries, and cooperation with other organizations. CORM's sixth report of Pressing Problems and Projected National Needs in Optical Radiation Measurements came out last December.

Because CORM has been so effective in helping us set priorities for optical radiation measurement, in 1993 we established a similar organization representing thousands of users of ionizing radiation, the Council for Ionizing Radiation Measurements and Standards (CIRMS). CIRMS has now published its first report on National Needs in Ionizing Radiation Measurements. Such radiation includes high energy ultraviolet light, x-rays, gamma rays, and energetic particles including electrons, protons and neutrons. Technological applications include diagnostic and therapeutic radiology, radioisotope imaging, radiation protection and radiation processing.

For our third service-oriented division, Time and Frequency, we use a different approach to setting priorities because of the different nature of our constituency. Here we receive about 6000 calls and 3500 written inquiries a year. And in addition to our direct one-on-one contact with customers, we interact closely with the manufacturers of devices dependent on our services, who in turn interact with the customers. So we have two routes for finding out about customers' concerns and needs. We also use periodic surveys, which we publish in the magazines and journals that our customers are likely to read. These surveys provide important confirmation of what we've been hearing all along—and also more quantitative information on who is interested in what services. In the last survey, we had 6000 responses to what was a detailed and demanding questionnaire.

So if we work closely with our customers in setting priorities for our service-oriented programs, how do we decide on our longer term programs of fundamental research? For any scientist and scientific institution, this is a continuous process. For NIST the basic question is, “Do our research programs meet the present and future measurement needs of the United States?” One way our scientists attempt to answer this question is by attending meetings held by professional societies, identifying the most exciting or relevant projects, and then deciding whether the ideas generated by this process can compete with research programs already in place or being planned at NIST.

Measuring Results

As with setting priorities, we look to our councils (CORM and CIRMS), our surveys, and our many interactions with industry for feedback on how we are performing our jobs.

As a recent experiment in the Physics Laboratory, we have initiated several economic impact studies. The most comprehensive are those performed by independent contracted researchers who examine rates of return realized from investment in a given type of technology and in different stages of the technology's development by measuring and quantifying the economic returns from our research and services. In these studies, the rate of return is computed in the same way that rates of return are calculated from the time flows of costs and benefits associated with a particular project or investment in the business and financial communities. The results provide another perspective on the value that U.S. taxpayers realize from their investment in our programs. A recent study on the economic impact of the Spectral Irradiance Standard indicated that the social rate of return is 145 percent. This rate is higher than that reported in recent studies on private-sector R&D investments and academic research.

Because much of our fundamental science is designed to anticipate the Nation's measurement needs, the central issue in assessing it lies in defining the goal against which progress is to be measured. Leadership across the frontiers of scientific knowledge is at the heart of that goal. It assures that American scientists are expanding the knowledge base at the leading edge. Merit review based on peer evaluation continues to be the primary vehicle for assessing excellence and leadership of fundamental science programs. Accordingly, the significance of the Laboratory's contributions is assessed by prestigious awards, publication of results in prestigious journals, and invitations to present talks at prestigious national and international conferences. For example, the significance of the Laboratory's contributions has been acknowledged by receipt of almost every prize (often more than once) in atomic, molecular and optical physics awarded by the relevant professional societies. Three of our scientists are members of the National Academy. One was cited in the 1989 Nobel Prize for Physics. Another received a standing ovation at an international conference this past summer for the first demonstration of Bose-Einstein Condensation.

In addition, all of the technical programs of the Physics Laboratory are reviewed annually by external panels convened by the National Research Council. The panels consist of scientists, engineers and technical managers from academia, industry and government. They assess the technical quality and effectiveness of our programs, our priorities and priority setting process, and our impact on industry and how this impact is measured. This process for evaluating our programs has, with some modifications, been used effectively for 37 years.

Summary

I hope that I have given you some sense of the research we do in the Physics Laboratory both to respond to the Nation's immediate measurement needs and to anticipate its future needs. I hope, too, that I have made it clear why we need a cadre of the world's leading scientists to tackle the measurement challenges that no company or industry or university department could possibly undertake.

I will be happy to answer any questions you may have.

Mrs. MORELLA. Very good. You were very succinct.

I note that you have more of an elucidation in the testimony that you have given us in terms of the four thrusts, and we might refer to that when we do some questioning.

Dr. Patel, we would love to hear from you.

STATEMENT OF DR. C. KUMAR PATEL, VICE CHANCELLOR, RESEARCH OFFICE, UNIVERSITY OF CALIFORNIA

Dr. PATEL. Madam Chairwoman, and Members of the Committee:

I would like to thank you for allowing me this opportunity to share with you my views on the importance of scientific research being done at the Physics Laboratory of NIST.

I am going to restrict my comments to the value the academic and industrial research community has derived from the Physics Laboratory. My full comments are available in the detailed statement.

We know that, and we just heard, the Physics Laboratory is a world-class organization in the general area of atomic measurements and standards in physics. Many of these activities are strongly coupled with the principal missions of NIST of creating, maintaining, and propagating standards for frequency and time, voltage, and length.

In doing so, the Physics Laboratory interfaces very strongly with the academic and industrial scientific community.

I will not directly describe the outstanding scientific achievements of the laboratory, but concentrate on the ways in which the academic and industrial scientific community benefits from them.

There are four interaction mechanisms I would like to briefly describe. These are all connected with academic and industrial scientists with Physics Lab scientists at NIST.

The first of these programs is the Visiting Fellows Program. This is a mechanism by which academic or industrial scientists can spend extended periods of time working at NIST Laboratories and take advantage of the instrumentation and the high level of expertise that is resident in NIST.

Each year there are some 10 visiting fellows. One position is generally occupied by an industrial scientist which allows NIST to accomplish the science and technology diffusion.

This program has attracted the best scientists from all over the country. As a matter of record, Congressman Vern Ehlers, who was recently elected to Fellowship in the APS, was a NIST Fellow in his prior career as a physicist.

The second program which has benefitted universities is NIST's Graduate Student Program through which students can do their thesis, Ph.D. thesis, at NIST working with a world-class scientist and with state-of-the-art instrumentation I just mentioned.

By necessity, large numbers of registrants have come from the University of Colorado where NIST has its Physics Laboratory. Nonetheless, there are registrants from other universities also, and what this does is it provides outstanding education and training opportunities for the next generation of scientists.

The third of these programs is joint experimental activity between NIST Physics Laboratory scientists and the academic faculty members, often driven by unique experimental facilities at NIST which would be too expensive to reproduce at each one of the academic institutions.

Two of the recent outstanding achievements from NIST, we just heard about the Bose-Einstein condensation. The second one is a laser which does not require the traditional inversion in an atomic or molecular system.

Both had faculty collaborators from the University of Colorado and the Texas A&M, respectfully. The complete list is too long, and I will not describe that for the time being.

Finally, NIST Physics Laboratory provides unique contributions to a number of academic and industrial R&D scientists through providing instrumentation calibration which is an absolute must for precise and reproducible experimental observations.

Without such calibrations, we would either have chaos in the field of science because no experiment would be able to confirm the earlier quantitative observations; or each scientific team will have to generate its own absolute standards which would be an unreasonably expensive proposition.

There are other areas in which NIST Physics Laboratory makes significant contributions to academic and industrial R&D.

These, for example, include development and propagation of unique instrumentation critical for experimental physics.

I do not have time to describe these here, but the details can be found in the written testimony.

Let me stop here and thank you for allowing me to present my views.

[The prepared statement of Dr. Patel follows:]

Testimony of Dr. C. Kumar N. Patel
Vice Chancellor, Research (University of California, Los Angeles),
President of The American Physical Society (1995),
and
President of Sigma Xi, The Scientific Research Society (1993-1995)

BEFORE THE

Subcommittee on Technology,
Committee on Science, House of Representatives,

on

Reauthorization of NIST Laboratory Programs

Thursday May 2, 1996

Chairwoman Morella and Members of the Subcommittee, I appreciate this opportunity to testify today about the importance of the work being done in the Physics Laboratory at the National Institute of Standards and Technology. I have chosen to focus my remarks on the value the academic and industnal scientific community has derived from the activities of the Physics Laboratory at the National Institute of Standards and Technology. Before I proceed, however, I should like to point out that during the past year my colleagues and I from the American Physical Society have publicly supported the research activities at NIST. Last year, as then President of the APS, I obtained the support of a number of other professional societies to be signatories to a statement which ennumerated the value of NIST to our Nation. A large number of Nobel Prize winners also chose to craft their own statement to this effect. Both of these statements were publicly presented at a press conference in Washington , DC on September 11, 1995; and are included at the end of my testimony.

Now to return to the present theme, the Physics Laboratory's strengths include its multiple contributions to basic physics, chemistry, and material science and its seminal role in fundamental measurement technology. The Laboratory realizes that its mandate to support both directed fundamental and applied activities is an advantage. The programs that support the more fundamental activities also provide the standards and technology necessary to improve research areas in industry and government. It is worth pointing out that there is a synergistic relationship between science, technology, and standards. An outstanding example of this is a new phenomenon called the Quantized Hall Effect became possible because technology of making ultrapure thin layers of semiconductors. Some of this has its genesis in the standards activities of NIST of many years ago. This scientific discovery allowed NIST scientists to exploit the phenomenon for creating an absolute voltage standard that depends only on the fundamental constants of nature. In turn, this technological use as a standard has promoted new scientific directions in semiconductor materials research. The feedback goes on. In the future, we will have new technologies and industries in which other quantities, too, will be measured in terms of fundamental constants of nature. For example, distances will be measured in terms of the size of atoms rather than the wavelength of light. Innovative standards and new measurement techniques will be essential to their development.

The Physics Laboratory has maintained a close connection with the academic community. One of the closest connections has been with the University of Colorado in Boulder Colorado. A cooperative enterprise between the NIST Physics Laboratory and the University of Colorado, JILA (formerly the Joint Institute for Laboratory Astrophysics), was established to formalize this relationship. A Division of the Physics Laboratory is permanently located at Boulder in JILA. This Division conducts advanced research in atomic and chemical physics, and laser and optical physics. The Physics Laboratory staff in Boulder have the opportunity and responsibility to participate in faculty activities and supervise graduate students and postdoctorals. At the present time 66 graduate students and postdoctorals are being supervised by Physics Laboratory staff. The University of Colorado has derived many benefits from JILA. It has made possible a large concentration (critical mass) of scientific talent in certain specialized areas. It has also provided the university with a core of high caliber research scientists who, through their visibility in the scientific community, contribute to the university's stature.

The above factors cause the University of Colorado to attract some of the best graduate students in the country. Recently the weekly magazine U.S. News and World Report rated the University of Colorado the top graduate school in the field of atomic and molecular physics. The JILA relationship has been a very fruitful one. JILA scientists were the first to demonstrate Bose Einstein Condensation. In this work a laser-trapped assembly of atoms was cooled to a record low temperature where it condensed into a new state of matter originally predicted to exist by Bose and Einstein in 1924. Its fundamental properties, still being investigated, will form the basis for new sensors and length and frequency measurement techniques.

The Physics Laboratory is involved with the academic and industrial R&D community in a number of ways including: the JILA Visiting Fellows Program, a graduate students program, collaborations, which allow both NIST and academia and industry to broaden their research efforts; development and calibration of instruments which are used by the academic and industrial R&D community; and research projects which support the academic efforts at various universities.

EXAMPLES OF ACTIVITIES WHICH SUPPORT THE ACADEMIC AND INDUSTRIAL R&D COMMUNITY

VISITING FELLOWS PROGRAM:

The JILA Visiting Fellows program provides partial funding for about 10 internationally distinguished scientists per year to spend up to 12 months at JILA collaborating with resident scientists. One Fellowship per year is designated specifically for a U.S. industrial scientist. Most of Visiting Fellows have some support from their home institutions. The remaining financial support is provided by NIST through a contract to the University of Colorado.

Key Areas that attract Visiting Fellows include frontier research in atomic and chemical physics and in laser and optical physics, where they have the opportunity to work with groups of high caliber research scientists with high visibility in the scientific community. One recent Visiting Fellow studied the dynamics of molecules on semiconductor surfaces; another spearheaded an effort to develop a discharge slit nozzle source for free radicals; yet another studied phase shifts and intensity dependence in frequency modulation spectroscopy.

It is interesting to note that Congressman Dr. Vern Ehlers, who was recently elected a Fellow of the American Physical Society, was a Visiting Fellow for 1971-1972

The Visiting Fellows (from the U.S.) for 1994-96 include: Joel Bowman (Emory University); John Delos (College of William & Mary); Stephen Rand (University of Michigan); John Smedley (Bates College); Timothy Zwier (Purdue University); Edgar Knobloch (University of California): Marc Levenson (IBM, Almaden): Chii-dong Lin (Kansas State University); and Krzysztof Szalewicz (University of Delaware).

GRADUATE STUDENTS:

The Physics Laboratory has nine graduate students from schools other than the University of Colorado: four from the University of Maryland, three from the Colorado School of Mines, one from the University of Missouri, and one trom the University of Michigan. NISTalso has 17 post-docs from Harvard, Princeton, Yale, MIT, University of California at Berkeley, University of Chicago and University of Texas.

COLLABORATIVE RESEARCH WITH ACADEMIC AND INDUSTRY SCIENTISTS:

The Physics Laboratory's most recent scientific discovery was the first observation of Bose-Einstein Condensation by Eric Cornell of the Physics Laboratory in collaboration with Carl Wieman of the Physics Department of the University of Colorado, together with a postdoc and two students also from Colorado's Physics Department.

Physics Laboratory scientists in collaboration with Harvard University researchers have used neutral atoms to write patterns on silicon. The new method offers the promise of a form of microlithography allowing integrated circuits or other microfabricated objects to be manufactured about 10 times smaller than is possible with light-based lithography methods.

Leo Hollberg of the Physics Laboratory recently demonstrated lasing without population inversion in collaboration with scientists at Texas A&M, work that could lead to very high energy light photons, or even x-rays, from lasers.

The so-called Lightfab program, supported by NSF, has allowed the Physics Laboratory to collaborate with Harvard and (initially) AT&T Bell Laboratories in the use of optical techniques to study the attachment of viruses to living cells.

Scientists in the Physics Laboratory are collaborating with colleagues at the University of Maryland to study the use of fullerenes to transport radioactive material to tumors in the human body.

The Physics Laboratory's program in photoassociative spectroscopy formed the basis of an aggressive program in this area at the University of Maryland. NIST's pioneering efforts in cooling of atoms have spawned major programs in this area at Harvard and SUNY Stony Brook. The techniques that NIST developed for stabilizing lasers are being used world-wide and have led to similar programs at Stanford and the California Institute of Technology.

INSTRUMENTATION IN SUPPORT OF SCIENCE:

The Physics Laboratory developed an instrument (based on Fourier Transform Microwave Spectroscopy) which can detect small gas-phase clusters and large organic species. This instrument has unprecedented sensitivity and 100% selectivity. This makes the instrument well suited for trace gas analysis for low levels of impurities in process gas streams. The Physics Laboratory has hosted many visitors from universities who have worked with this device and subsequently returned to their home institutions and produced copies of the NIST instrument. At the present time, there are more than 20 instruments of this type at universities, most of which are patterned after the NIST design.

The Physics Laboratory calibrated instruments for the Near Infrared Camera and Multi-Object Spectrograph to be put on the Hubble telescope in February of 1997. This work is for NASA but is used by a large number of university scientists.

ACTIVITIES WITH INDUSTRIAL R&D COMMUNITY:

The Physics Laboratory is working with the semiconductor industry to grow and characterize very thin uniform films, with the lighting industry to develop mercury-free fluorescent lighting starting with the basic cross sections for excitation of the various states; with a large U. S. manufacturer to investigate surface defects in the magnetic domain structure of the magnetic glasses used as cores in most power distribution transformers, and with an electronics company to diagnose a mysterious failure in a new type of memory element.

SUPPORT OF NATIONAL LABORATORIES AND OTHER AGENCIES:

NIST's role in the creation of the modern GPS system was supportive to DoD and its contractors. In the mid-1970's, NIST had input on how the GPS ground monitoring stations should be set up and how the analysis of time data should be used. We have worked with them on clock problems and characterization of components. Several NIST scientists served on committees studying these aspects of GPS.

Today, NIST has a contract with the GPS operators to assist in evaluating the performance of the satellites. In particular, NIST developed a method, called the Common View Method, of transmitting time and frequency information with great accuracy. This method is used--and relied upon--by high-end users, such as the Jet Propulsion Laboratory, who need very accurate timing information. It is not used by more routine customers.

The Physics Laboratory has played and continues to play an important role in providing the standards and calibrations for optical instruments on NASA space missions. The wide range of capabilities at the Laboratory allow such instruments to be calibrated for infrared through ultraviolet light and for x-rays. For example the Laboratory provided vital standards, characterizations and calibrations used to analyze the images seen by scientific instruments on the Hubble space telescope. This is a particularly challenging project due to the very low intensity of the light emitted by the faint astronomical sources such as quasars, planetary nebulae, and white dwarfs. One particular calibration for a platinum lamp which is now on-board the Hubble Space Telescope is allowing scientists to measure velocities of stars to improved levels of accuracy.

For Industrial R&D in commercial use of GPS, NIST provides calibrations of commercial receivers and study algorithms for processing GPS data in the presence of selective availability (intentional degradation put on by DoD). The use of GPS for civilian applications has a multi-billion dollar impact. Since many organizations have worked on GPS, it is difficult, if not hopeless to single out the value of NIST's contribution.

PROGRAMS

The Physics Laboratory has a very long-standing comprehensive effort focused on studies of laser cooling and electromagnetic trapping and manipulation of atoms and ions. This work has led to a number of break-throughs in technology including: the first laser cooling; the first laser cooling of atomic beams; the first trap for neutral atoms; and the first sub-Doppler cooling, which at the time produced cooling that was 100 times lower than was obtained previously. These advances were important steps which led to the first production of Bose Einstein condensation.

The Physics Laboratory has played and continues to play an important role in providing the standards and calibrations for optical instruments on NASA space missions. The wide range of capabilities at the Laboratory allow such instruments to be calibrated for infrared through ultraviolet light and for x-rays. For example the Laboratory provided vital standards, characterizations and calibrations used to analyze the images seen by scientific instruments on the Hubble

space telescope. This is a particularly challenging project due to the very low intensity of the light emitted by the faint astronomical sources such as quasars, planetary nebulae, and white dwarfs. One particular calibration for a platinum lamp which is now on-board the Hubble Space Telescope is allowing scientists to measure velocities of stars to improved levels of accuracy.

The first low energy polarized electron source was developed in the Physics Laboratory. This source made it possible, for the first time, to produce a beam of electrons with controllable spin polarization, yet with an intensity equal to that of an unpolarized beam. This revolutionized polarized electron physics because a beam with modulated spin polarization could replace a conventional electron beam and the measurements would reveal the spin dependent part of the electron's interaction. The source is now universally used as the primary source for spin polarized electrons in atomic, molecular, condensed matter and high energy physics.

The first experiment to use polarized electrons scattered from the surface of a ferromagnet to study surface magnetism was performed at the Physics Laboratory.

The first measurement of the polarization and energy distribution of secondary electrons from a ferromagnet was made at NIST. The demonstration that the polarization of the secondary electrons ejected from the surface reflected the surface magnetization, led to the proposal that imaging of magnetic domains at high spatial resolution would be possible through the use of a scanning electron microscope and a spin polarization detector. This was later called scanning electron microscopy with polarization analysis or SEMPA. This instrument has been used to investigate surface defects in the magnetic domain structure of magnetic glasses used as cores in most power distribution transformers. Such investigations may ultimately allow more efficient transformers to be produced.

Physics Laboratory scientists have provided standardized x-ray sources used to calibrate x-ray fiber optic collimators for x-ray lithography.

Atomic structure data established from innovative theoretical and experimental approaches have been compiled for a number of atoms. The concentration has been on the spectra for neutral and lowly ionized atoms , however work is underway on highly ionized atoms of scientific interest. The compilations contain detailed information such as spectroscopic configurations which are of great value to university researchers in developing their research plans.

FACILITIES

The Physics Laboratory has many facilities which offer excellent capabilities for use in research programs. Some of the major facilities with significant efforts directed towards fundamental science studies are:

- Synchrotron Ultraviolet Radiation Facility. A 300 MeV electron storage ring which provides synchrotron radiation which is highly collimated, nearly linearly polarized, and of calculable intensity. It is used for fundamental research in atomic, molecular, biomolecular and solid-state physics.

  This facility is used by 23 faculty from 9 academic institutions, and 26 scientists from 9 government laboratories.

- Medical Industrial Radiation Facility. A 7-32 MeV electron accelerator which is being used in a number of university collaborations programs such as radiation effects on electronics, channeling radiation and coherent Bremsstrahlung.

  This facility has attracted 15 collaborators from 10 academic and industrial institutions.

- Electron Beam Ion Trap. Designed to produce, trap, and excite highly-charged ions for atomic physics studies. Compared to other sources of highly charged ions, the ions from EBIT are cold so the Doppler corrections are not significant.

  Because of the unique nature of this facility, joint activities with 20 collaborators fro 15 academic institutions have been carried out.

- Neutron Interferometer and Optics Facility. Located in the Guide Hall of the NIST research reactor, this is one of the world's premier user facilities for neutron interferometry and related neutron optical measurements. Measurements are made to study the magnetic, nuclear, and structural properties of materials, as well fundamental questions in quantum physics. Related, innovative neutron optical techniques for use in condensed matter and materials science research are being developed.

  These facilities provide standards based calibration services to a variety of sectors: 32 academic institutions, 17 government laboratories, and 31 industrial organizations.

Kumar Patel is the Vice Chancellor for Research at UCLA. Prior to joining UCLA in 1993, He was the Executive Director of Materials Science, Engineering and Academic Affairs Division of AT&T Bell Laboratories where his professional career has consisted of his being a scientist, engineer, and manager of research with AT&T Bell Laboratories. In addition, he is the past President (1993-1995) of Sigma XI, The Scientific Research Society, a broadly based science society whose more than 94,000 members reside in every one of the States of U.S. He is also the past President (1995) of the American Physical Society whose membership includes more than 43,000 physicists.

APPENDIX

The American Physical Society
One Physics Ellipse, College Park, MD 20740-3844 (301) 209-3268

President
C. Kumar N. Patel
University of California, Los Angeles

September 11, 1995

As presidents and directors of professional societies representing more than 1,000,000 experts in engineering and in the mathematical, physical and medical sciences and with concern for the strength of the nation's scientific enterprise, we urge you to maintain federal support for the laboratories of the National Institute of Standards and Technology.

The NIST laboratories uniquely serve the broad scientific and technical community. Scientists and engineers from nearly every state in the country come to the NIST laboratories to carry out their research. Consequently, the NIST laboratories have a strong record of contributing to the nation's technological and scientific competitiveness and are a crucial component of the nation's long-term basic research.

We recognize that your effort to balance the budget is forcing tough choices regarding the Department of Commerce. However, the laboratories operated by NIST and funded by the Department of Commerce are a vital scientific resource for the nation and should be preserved in the process of downsizing the federal government.

Sincerely,

Dr. Robert E. Apfel
President
Accoustical Society of America

Dr. Guy Simmons
President
American Association of Physicists in Medicine

Dr. Hugo Steinfink
President
American Crystallographic Association

Richard D'Eustachio
President
American Dental Association

Roland W. Schmitt
Dr. Roland W. Schmitt
Chair
American Institute of Physics

John Graham
John Graham
President
American Nuclear Society

David Schnakenberg
Dr. David Schnakenberg
Executive Officer
American Society for Clinical Nutrition

John H Weaver
Dr. John Weaver
President
American Vacuum Society

Robert A. Laudise
Dr. Robert A. Laudise
President
Federation of Materials Societies

Richard Herman
Dr. Richard Herman
Chair
Joint Policy Board for Mathematics

Jerold Roschwalb
Jerold Roschwalb
Director
National Association of State Universities
and Land-Grant Colleges

Cathleen Synge Morawetz
Dr. Cathleen S. Morawetz
President
American Mathematical Society

Kumar Patel
Dr. Kumar Patel
President
American Physical Society

Arthur J. Atkinson
Dr. Arthur J. Atkinson
President
American Society for Clinical
Pharmacology and Therapeutics

Pings
Dr. Cornelius J. Pings
President
Association of American Universities

Paul E. Almeida
Paul E. Almeida
President
International Federation of Professional
and Technical Engineers

Kenneth A. Ross
Dr. Kenneth A. Ross
President
Mathematical Association of America

Margaret H. Wright
Dr. Margaret Wright
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September 11, 1995

As recipients of the Nobel Prize in physics, we are writing to emphasize the essential role to the nation of the NIST laboratories and to urge that federal funding for these facilities be maintained in the process of downsizing or reorganizing the Department of Commerce.

In support of NIST's fundamental task to provide unique measurement capabilities for industry, NIST's laboratories carry out the basic research that is essential for advanced technology. They provide the know-how to maintain and improve our measurement and calibration capability in areas such as time, power and materials, and in health and medicine. It is unthinkable that a modern nation could expect to remain competitive without these services.

The NIST laboratories carry out research for the Department of Defense and many other branches of the federal government. Their facilities are used by scientists from across the nation, and their staff includes some of the nation's leading scientists and engineers.

Measurements and standards techniques from the NIST laboratories have been estimated to save the nation billions of dollars annually through their use in industries such as electrical power, semiconductor manufacturing, medical, agricultural, food processing, and building materials. The loss of these laboratories would be a serious blow to our long-term technological capability and to our national enterprise in basic research.

We urge you to make every possible effort to preserve this national treasure.

Yours truly,

Norman F. Ramsey

Norman F. Ramsey
Higgins Professor of Physics, Emeritus

Philip W. Anderson
Philip W. Anderson
Princeton University

Hans A. Bethe
Hans A. Bethe
Cornell University

Nicolaas Bloembergen
Nicolaas Bloembergen
Harvard University

James Cronin
James W. Cronin
University of Chicago

Hans Dehmelt
Hans Dehmelt
University of Washington

Jerome I. Friedman
Jerome I. Friedman
Massachusetts Institute of Technology

Val L. Fitch
Val L. Fitch
Princeton University

Sheldon Lee Glashow
Sheldon Lee Glashow
Harvard University

Ivar Giaever
Ivar Giaever
Rensselaer Polytech Institute

Russell Hulse
Russell A. Hulse
Princeton University

Henry W Kendall
Henry W. Kendall
Massachussetts Institute of Technology

Leon M. Lederman
Leon M. Lederman
Fermilab

Arno Penzias
Arno A. Penzias
AT&T Bell Laboratories

Edward Purcell
Edward M. Purcell
Harvard University

Burton Richter
Burton Richter
Stanford University

Arthur L. Schawlow
Arthur L. Schawlow
Stanford University

J. Robert Schrieffer
J. Robert Schrieffer
Florida State University

Clifford G. Shull
Clifford G. Shull
Massachusetts Institute of Technology

JH Taylor
Joseph H. Taylor
Princeton University

Chas. H. Townes
Charles H. Townes
University of California, Berkeley

Steven Weinberg
Steven Weinberg
University of Texas, Austin

Kenneth G. Wilson
Kenneth G. Wilson
Ohio State University

Robert R. Wilson
Robert R. Wilson
Columbia University

C. N. Yang
C.N. Yang
SUNY at Stony Brook

Mrs. MORELLA. Thank you, Dr. Patel.

Dr. Paliwal—you are all adhering to even under the five-minute rule. If only Congress could follow the kinds of tenets that we hold out to others.

Dr. PATEL. That was two minutes.

STATEMENT OF DR. BUHDATT PALIWAL, PROFESSOR OF HUMAN ONCOLOGY, UNIVERSITY OF WISCONSIN

Dr. PALIWAL. I think they were saving time for me. I speak slowly.

[Laughter.]

Dr. PALIWAL. Chairwoman Morella, Distinguished Members of the Committee:

I am really pleased to be here to represent the American Association of Physicists in Medicine. This is the largest health-care organization that participates in patient management in many aspects from the physics point of view.

We relate very closely with NIST in our routine activity. Some of the activities that we participate in impacts, to give you some figures, on the order of 300 million procedures a year.

About 600,000 cancer patients a year are impacted by the information that we receive from NIST. Because all of our instrumentation, all of our treatment machines, all of our varieties of instruments, the radioactive isotopes that we use in this practice, they derive their fundamental calibration from the procedures and cooperation that we have with NIST.

It is from that perspective I feel it is an important area, and I will cover some other aspects of the development, the revolution that is going on in technology in medicine that is going to impact also in the future the competitive aspects of it.

So I feel really privileged to be here to speak on behalf of this particular issue of NIST activity.

Actually, the need for this kind of effort was recognized by Dr. Lauriston Taylor as early as 1927 when this aspect of standardization was put into practice.

There were some medical physicists like Bob Loevinger who actually came from a clinical program and became a staff member at NIST who saw these needs and further enhanced this activity as part of the NIST program. He set up multiple calibration lab so that most of the major burden does not go to the host institution; they are what is called credited calibration laboratory that relate to NIST and provide the dissemination of the information on a larger scale because NIST by itself will be unable to handle all that. So that is the second aspect of historical perspective of the activity of this organization.

The third, and really the most important issue that I really want to emphasize here today, is the critical example of the needs of credibility of measurement standards that are utilized in the mammography procedures.

You know, we heard about California and these technologies, and Silicon Valley and these technologies, but I think the farmers in Wisconsin and women all over the country need this standardization.

There is a need for—there is such a proliferation of devices that are utilized for mammography procedures on a routine basis, and the accreditation mandated by the MQSA Public Law 109-539 by the Congress that certain quality standards are met in these activities.

In order to really implement that and keep those standards high, you have to have this accountability and traceability through the national standards.

The next part of this operation relates to some of the new technology that is developing in the field. Some of these isotopes, which are of the order of a millimeter-by-millimeter square, and they are mounted on very small wires. They can be transported into the body intravenously and intra-arterially, and the configuration-specific calibrations of these sources is extremely important. It will impact thousands of people who have angioplasty, and they will be irradiated by these sources.

Now if we do not have these standards, we cannot really have a consistent qualitative and quantitative way of performing these procedures nationally. You can think of the disasters that would impact and the toxicity it would create if these are not standardized.

There is no organization in this country that can do this other than NIST.

To give a perspective, the only other institution in the world that has this kind of facility is the German Standards Lab, but I think we have to have this in our country. This is something that we cannot out-source to Mexico, for example.

Anyway, so that is the perspective and the necessity and the need for this support from NIST to the community for these kind of services.

Thank you.

[The prepared statement of Mr. Paliwal follows:]

Testimony for Dr. Bhudatt Paliwal
President, American Association of Physicists in Medicine

for Subcommittee on Technology

U.S. House of Representatives Committee on Science

Thursday May 2, 1996

Importance of Accurate Measurement Standards in Radiation Therapy and Radiology

Chairwoman Morella, as president of the American Association of Physicists in Medicine (AAPM), the largest organization in the world of physicists who work in health care, I am delighted to testify today about the importance medical physics places on accurate national standards at the NIST. Diagnostic and therapeutic health care today rely in large measure on our members working with the Physics Laboratory at NIST through secondary laboratories called Accredited Dosimetry Calibration Laboratories (ADCL). This collaborative relationship is shown in Chart 1 for diagnostic radiology facilities and Chart 2 for therapy clinics. In this manner, uniformity, and concomitantly quality and safety, is ensured for over 300 million diagnostic radiological procedures (ACR quote) and for an estimated 600,000 cancer patients who receive therapeutic doses of radiation (based on 60% receiving radiation therapy of the 1.1 million new cancer patients per year as determined by the American Cancer Society). Our nation needs to maintain primary standards to keep radiation doses accurate and as low as reasonably possible as well as achieving good image quality.

Traceability of Standards of X-Radiography in the United States

In all major industrial countries the primary standards for ionizing radiation reside in a central government standards laboratory. In the US, this need was recognized as early as 1925. In 1927, Lauriston S. Taylor established a basis for x-ray standards at NIST to support the US medical physics community. In about 1970, through the efforts of Robert Loevinger at NIST and several members of our association, we set up a system of regional accredited dosimetry calibration laboratories (ADCLs). These five laboratories, which maintain very close contact with NIST staff, perform the essential calibrations for the thousands of users, tertiary laboratories, and instrument manufacturers in the US health care community. Chart 3 shows the increase in calibrations for therapy applications since 1974 performed through this collaborative relationship. This is a model system, which is the envy of the entire world. It serves at once to 1) lower costs, by obviating the need for several groups to develop standards, 2) improve the access to calibration services, since there is a well-defined system in place that works on demands of the marketplace, and 3) of utmost importance, strengthen the credibility of everyone making measurements; since traceability to national standards at NIST through an unbroken chain can be demonstrated.

Primary Standards for Mammographic Radiation Exposure and Kilovoltage at NIST

A critical example of the needs for credibility of measurements are radiation standards for x-ray mammography. The White House, several government agencies, and the Congress have long recognized both the needs for more widespread use of mammography and for greater uniformity of services to those women obtaining mammograms. There is a clear linkage here, in that women are demanding certification of the mammography facilities, and standards for physical measurements (along with training for radiologic technicians) are key to establishing this credibility. This was recently recognized by Congress by the establishment of the Mammography Quality Standards Act of 1992 (public Law 102-539).

The NIST Physics Laboratory has recently set up a world-class calibration range for x-ray beam qualities that are needed to serve our calibration laboratories, manufacturers and clinics. The state-of-the-art system has molybdenum- and rhodium-anode x-ray tubes and filters to allow tests of mammography instruments from a range of US manufacturers. At the new NIST facility an AAPM Accredited Dosimetry Calibration Laboratory was able last month to test ten transfer ionization chambers at ten new x-ray beam qualities. The only other laboratory in the world with comparable facilities is the German standards laboratory (Physikalisch-Technische Bundesanstalt). The Diagnostic Committee of AAPM considers it essential that primary standards for radiation exposure be maintained at NIST. It would be unacceptable and cost ineffective to force US manufacturers and medical physicists to go to foreign standards laboratories for measurements as critical as radiation exposure. This procedure of using foreign laboratories also would compromise Mammography standards in the US since there would be no control over the standards.

The Physics Laboratory has also recently responded to another critical need by designing a new, more accurate method of measuring kilovoltage for x-ray units used in mammography. This will offer us a new tool for looking at the influence of x-ray energy on mammographic image quality. We are looking forward to having one of the new NIST spectrometers at the University of Wisconsin calibration laboratory. This will significantly enhance our capabilities in the secondary laboratories. It is a good example of the importance of having some of the NIST staff working to develop new standards that will take advantage of the next generation of radiographic equipment.

Assurance of Accurate Measurements at Secondary Laboratories & Clinics

With the increased interest and emphasis on x-ray mammography, we are experiencing more demands on our practicing medical physicists; more calibrations, on a wider range of instruments, and with more stringent accuracy requirements. NIST is working directly with AAPM task groups of Diagnostic Committee, with other federal agencies and the states, as well as other voluntary standards groups (International Electrotechnical Commission) to ensure that national standards are available to meet these new challenges. By serving as a highly competent, unbiased third party, NIST has been able to consistently show leadership in developing new consensus standards. We cannot over estimate the value this critical contribution from NIST makes to the quality of US health care.

Chart 1:

DIAGNOSTIC RADIOLOGY MEASUREMENTS

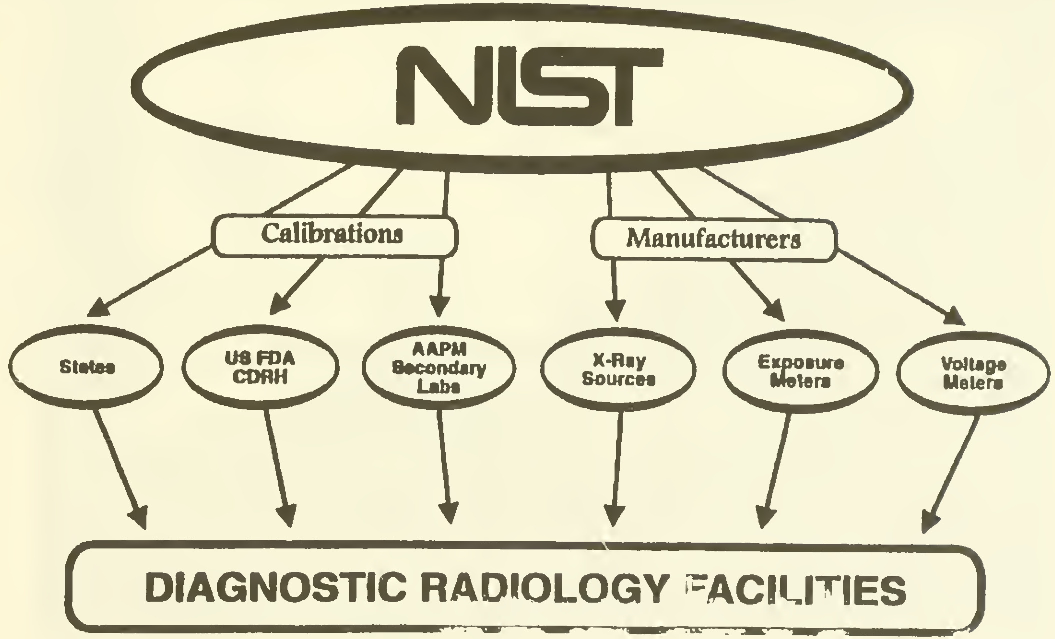


Chart 2:

THERAPEUTIC RADIOLOGY MEASUREMENTS

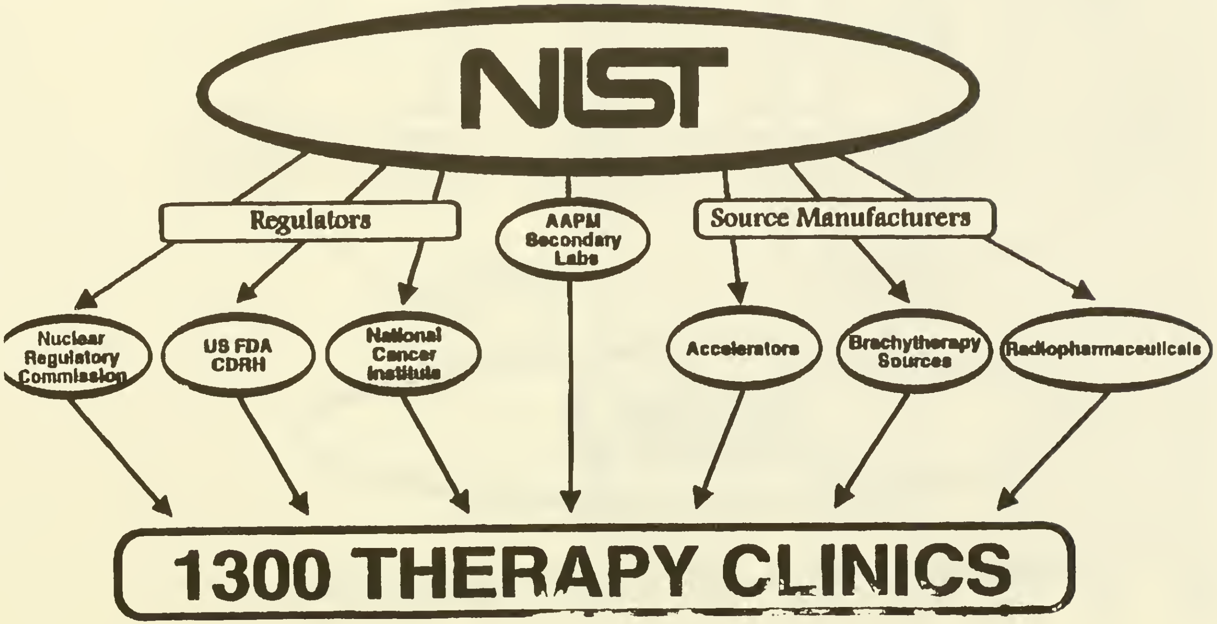
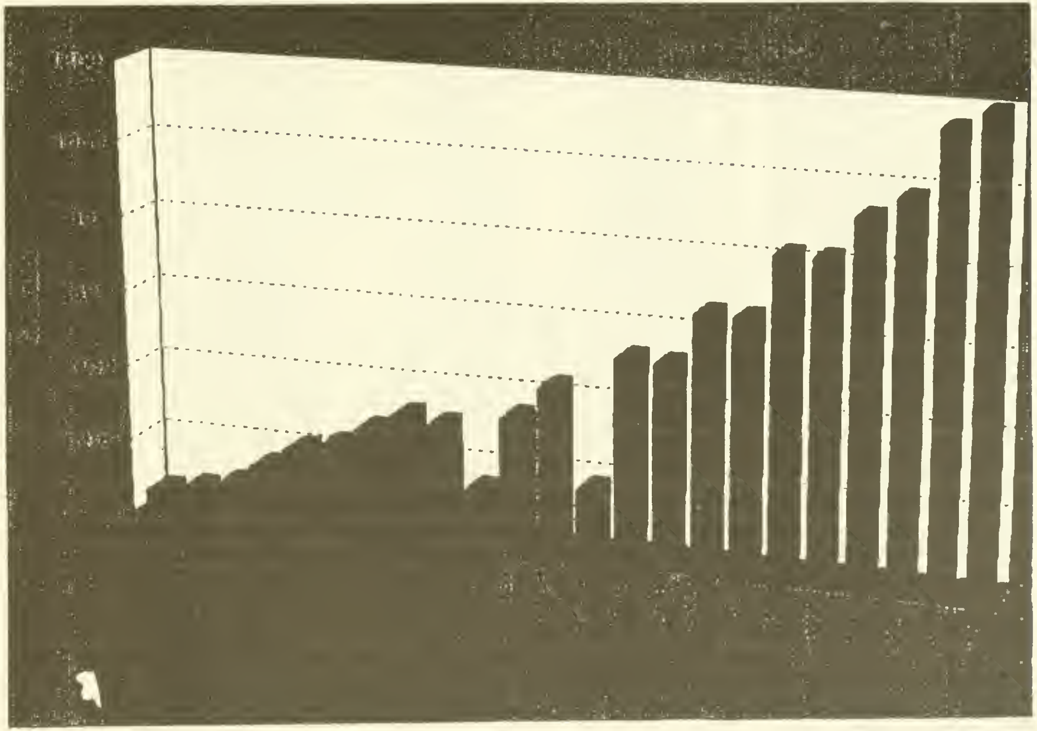


Chart 3: Cobalt calibration points



Other measurement standards at NIST are absolutely critical for the safe and orderly administration of ionizing radiation in US health care. I will mention specifically the following four:

Radiation absorbed dose standards for treatment beams of high energy x rays, electrons, and protons.

A majority of patients receiving ionizing radiation therapy today are treated with megavoltage x-rays and electrons from linear accelerators. The critical physical quantity that is maintained at NIST is the air kerma (formerly exposure) which is measured in the NIST cobalt-60 teletherapy source. NIST is currently working with the AAPM via TG #51 of Therapy Committee on a new absorbed dose to water protocol. NIST is also working with Harvard and Loma Linda on primary and secondary standards for proton accelerators. In addition NIST provides critical evaluated data on electron, photon and proton stopping powers that are used in radiation treatment planning.

Standards for radionuclides used for interstitial and intracavitary brachytherapy.

NIST has led the world in developing standards for iodine-125, iridium-192, and other radionuclides for use in interstitial therapy. If we are to establish baselines for clinical trials, we must have a reliable national standard for each source design. NIST has provided these standards for certain designs. For example, a major ocular melanoma study COMS relies on NIST standards for the iodine-125 seeds from Amersham Healthcare. They are also the only standards laboratory to provide standards for strontium-90 ophthalmic applicators.

New standards for intravascular brachytherapy.

A brand new, fast developing use of radiation in health care is intravascular brachytherapy using beta-emitting radionuclides to prevent restenosis following balloon angioplasty. This procedure could prevent restenosis in potentially hundreds of thousands of patients per year in the US alone. NIST has moved quickly to provide measurement standards for the strontium-90 sources used in this application. This is one more example of how the availability of standards from NIST can help us to introduce new effective treatment modalities.

Standards for radiopharmaceuticals used for bone palliation.

Finally, it has been estimated that 125,000 terminal cancer patients each year could be effectively treated for bone pain with radiopharmaceutical palliation agents, such as strontium-89. Although not a cure, the palliative agents greatly improve the quality of life for a large majority of the patients in clinical trials. NIST has led the world's standards laboratories in developing new radionuclide standards for therapeutic nuclides, including yttrium-90 for monoclonal antibodies, samarium-153 and strontium-89 for bone palliation, and holmium-166 for bone marrow ablation. These NIST standards greatly aid in the FDA review process for manufacturers and medical teams seeking clinical trials with new radionuclides.

Mrs. MORELLA. Thank you, Mr. Paliwal.

I guess I will start off the questions. We have been joined by Mr. Gutknecht on the subcommittee. I guess I could start off with something that is a basic question that deals with basic research and applied technology, something we have been discussing in this entire 104th Congress, and certainly before that, too.

Certainly any distinction between the two is not easy to draw. The technological innovation process is complex, and we are very often faced with the question of what is appropriate for federal funding?

What research and development costs should be borne by the private sector?

So I guess in light of that as a backdrop, my question to the three of you would be. How do you define when a measurement need is infrastructure and therefore appropriate for Federal support?

We need whatever guidance you can give us from your expertise. We can start anywhere you want. If you would like to start, Dr. Gebbie, or Mr. Paliwal.

Dr. GEBBIE. I think it is being increasingly recognized that the distinction between applied and basic research, between near- and long-term research is losing its usefulness as the two become more and more coupled.

In deciding on our priorities, we tend to think about whether something is—we tend to think about who is going to benefit. If its benefits are going to be broad and diffuse so that no single industry could capture the profits from it, then we feel that this is appropriate for the taxpayer.

If it is something that is simply going to benefit and provide a profit for a single company, then we feel that that is something that the private sector should support.

Dr. PATEL. Let me respond to this question based on my past experience. For some 32 years I was with AT&T Bell Laboratories before my moving to the University of California, so I have some experience with what the industry does and what it does not do.

One of the crucial features of industrial R&D is that it is carried out when it provides a competitive advantage to that particular firm or company.

Standards are something that help everybody and makes the entire industrial segment grow. Let me give you one example. The example is that of timing.

With the digital communications which are revolutionizing our communications industry for the last ten-or-so years, being able to keep time on a highly accurate basis becomes increasingly important.

If there are not standards for time, bit one may become zero, and your transaction for drawing money out from a bank may become drawing money out from your account into somebody's else account without your knowing.

So clearly this is something that is of importance to everybody. Activity like this is likely to benefit everybody because it grows the entire industry, no particular firm.

So it is unlikely that standard-setting in this kind of arena, that cost should be borne by one single firm. If it did, they will not propagate the standard; they will keep it for themselves to become rich. And I think all of us will be losers.

There are many examples where private institutions have set standards. One large software company is a prime example of that. I will not name the company, but it is clear that when that happens often the progress that keeps the United States industries competitive all over the world slows down.

So I believe that fundamental standards clearly have to be maintained by some kind of national organization funded by the government. Subsidiary standards or secondary standards is a different story.

Dr. PALIWAL. I think in our past experience we find the same or a similar analogy. What NIST provides is very basic at the grassroots level on which you build the rest of the structure.

To give an example, there are manufacturers that will produce X-ray machines. They have special targets. They are made up of very rare metals, rhodium and molybdenum, and some things of which you may not have heard. But because the characteristics of these particular targets, what kind of radiation they emit requires a specialized way of standardizing. Manufacturers don't care about it. They would like to go ahead and market it.

But on order to, from the safety point of view and the efficacy point of view and the cost-effective point of view, if it is done by one standardized place by an organization which has no vested interest, it comes up with a unique way of true standardization which is then followed and becomes the standard for the rest of the manufacturers.

In order to support even the development of manufacturing you have to have that in place so that that process can proceed, because then the regulatory agency and so on builds that the rest of the structure on this basic foundation.

So that in the case of mammography, for example, that is a process that has been in place. It is market forces that derive, but when it becomes a routine applied procedure, then the secondary labs, or the manufacturers can provide routine, day-to-day services; but it is the fundamental, up-front, in-the-beginning standardization activity. That is what NIST has been providing, and that is what we are asking for.

Mrs. MORELLA. Are there some instances where you then feel that the standardization objective of safety is not appropriate?

Now Dr. Gebbie said if it is going to help just one entity, and Dr. Patel brought out the fact that sometimes it is hard to say what the one entity is going to be, if it is going to assist others, and you seem to be pointing to the fact that it is necessary in all instances that we have an objective, federally supported role in the accuracy of the standards.

Dr. PALIWAL. Well that is what I feel in the medical field, particularly that is important that you have a very objective, standardized way to characterize things so that quality is maintained, that safety is maintained, and the effort is not duplicated by many institutions to try to set up their own standard. Then, there would be differences in standards and you would get the biases of the manufacturers, and so on.

So it makes sense to do it once, and for all the right way, at the right place with the right institution with the technical know-how in an objective way.

Mrs. MORELLA. I agree.

I will just ask one more question for this first round.

I visited, oh, sometime—well, I visit often—but some time ago when I was just brought into the mammography laboratory. As a matter of fact, I took some people from Montgomery County to make them aware of it.

I think that this subcommittee might like to know the relationship—as you said, the National Institutes is nearby--in terms of the mammography standards.

We sometimes think this is all handled by the National Institutes of Health. I wondered about what the relationship is, if you might kind of spell that out between these two wonderful public laboratories working together in terms of a detection, early detection, of breast cancer?

Well, Dr. Paliwal talked a lot about that.

Dr. Gebbie is there. Dr. Patel knows. So it's a toss-up, whoever wants to handle that.

Dr. GEBBIE. I could say very briefly that I think the distinction is very clear. The National Institutes of Health are responsible for doing the medical research on breast cancer, but we are responsible for providing the measurement standards that provide the infrastructure for this to happen.

The two are quite distinct. We are fulfilling the Constitutional responsibility of the Federal Government to provide these standards.

Dr. PALIWAL. I agree with what Dr. Gebbie said, but I will say another thing. I think you cannot do any research unless you have some standard to start with.

So I think without that standard, if people do research it will be very difficult to intercompare as to what different people did if there was no unique standard to start with.

That is where the two things have to happen in synchrony.

Mrs. MORELLA. You know, we passed legislation I think it was a session ago that dealt with the quality of the mammography itself.

Was that something that NIST was involved in?

Dr. PALIWAL. It was involved in the sense that NIST provided the calibration standards. If we are going to compare the quality, you have to have something to compare with, a unique level that you say you need to meet that criteria.

To establish that criteria, you have to have a set of parameters. These are the parameters, a subset of that, that NIST provided.

To give you an example, if you have a mammogram taken today, if you look at the image, the quality of that image depends upon the machine that was used.

In that machine there are components. Each of the components has a certain level of performance. If we are going to look at the variable that causes the quality of that image, then each of those variables have to be studied. If you do not have a standard to compare it with, you cannot really get back to what gives that best quality.

So NIST provides the basic calibration standards.

Mrs. MORELLA. We tend to forget how important standards are. We kind of take them for granted.

Well, I am going to now recognize other Members of the Subcommittee for any questioning they may have.

Ms. Lofgren?

Ms. LOFGREN. Thank you, Madam Chairwoman.

I wonder if any of you could briefly address what impact a 25 percent reduction in funding would have on the activities that NIST is currently engaged in in its core mission?

Dr. GEBBIE. NIST is already running at the very bare minimum. We are a very small fraction of the total R&D that is supported by the Federal Government.

We have not considered yet how we would take, specifically, a 25 percent cut.

Dr. PALIWAL. As a user dependent on NIST support, I would—because the current relationship that we want to have today and the things that are coming on the market that need development in the future, I would think a reduction would slow down that progress.

Development, for example, of some of the radioactive isotope standard that I talked about will have an impact on thousands of patients during angioplasty.

We cannot have those calibrated and standardized working without NIST. NIST has a small staff in the particular area that we relate to. Then, I think instead of doing it in six months it will take six years!

I think in terms of competitive edge, time is of the essence. If we don't do it today, somebody else has the capability. The other countries are also aggressively pursuing the same thing.

So that puts us technologically and commercially behind. So timing is very important in some of these matters.

Dr. PATEL. I think the notion of a 25 percent reduction brings to my mind not a slowing down of everything that happens, but a good manager would jettison one or many activities to keep other activities alive.

I think in the technological world that we live in, the number of fundamental activities that go on at the physics laboratories of NIST are interrelated.

There is no industry that I know of that you can say that if one particular type of activity was abandoned at NIST, you can put that segment of our industry and everything else would stay well.

I think the interconnection and interdependence of many of our industries, all of our industries, is to such an extent that the entire international competitiveness would suffer.

I think this is not a scientific decision. I think from the point of view of science one would ask the question. Is the work that is being done at NIST done most appropriately and most efficiently? Then, ask the question of what will happen if you arbitrarily decide what will happen with a 5 percent, 10 percent reduction.

It may well be that we may find that we may be able to improve the competitiveness of this country and improve the wealth of the Nation and increase the number of jobs held by Americans if you increase the funding.

I do not know the answer, but I think the correct question is. Let's figure out what the question is, and then begin to bring up the answers.

This is something, as I said earlier, comes from my earlier experience in industry where asking the right questions is more important than coming up with the answers up front.

Ms. LOFGREN. If I may, these are questions I am asking not because I am proposing them, but because they have been proposed by others.

The second question I have, really, is also encompassed in the proposal for dismantling of the Commerce Department, which is to eliminate NIST as a Federal agency and to privatize—I'm not sure exactly what that would mean, but I assume it would be taken over by a private entity and would be in some measure fee-supported by others.

How do you think that would work, just briefly?

Do you think that would work for our country?

Dr. PATEL. Late last year a similar proposal had come up, and at that time I was the president of the American Physical Society. The Physical Society took a well-measured and strong stand which indicated that privatizing this laboratory would do a serious harm to the activities which are being carried out at NIST.

Again, as we see the competitive pressures in the private sector, even the bastions like Bell Laboratories are reducing their fundamental research effort, principally because their aim is on the bottom line.

I think a privatized NIST laboratory will not be able to provide the functions, or provide the outcomes which we believe are important.

Incidentally, that statement regarding the importance of NIST to the Nation was supported by some 35 or 37 Nobel Prize winners in physics, also.

I think there is a general consensus amongst a large number of industrialists that a privatization probably is the wrong direction as far as NIST laboratories are concerned.

Ms. LOFGREN. Well I have never heard anyone in industry or science suggest it, but I have heard Members of Congress suggest it.

Dr. GEBBIE. I would like to emphasize your own words, that the research and development that is needed to provide the measurement infrastructure for the United States is a Constitutional responsibility of the Federal Government. No other institution, private or public, provides this function.

I think the private sector recognizes the importance of having this done and centrally executed in a reliable and fair fashion so that standards are never made the competitive pawn for a single element of the private sector.

Ms. LOFGREN. If I may, I will wind up now noting that we did adjourn last night, and we were supposed to be in session today but we got our work done early, and speaking of the Constitution, I am a member of the Judiciary Committee that is also looking at Due Process issues in the context of criminal law and fair notice. So I do have to drop in there. And it is not for a lack of interest in this, but hopefully I will be back.

Mrs. MORELLA. Thank you. I think our panelists all know the activities here in Congress where you have simultaneous hearings going on.

I did want to make note that this Subcommittee invited the author of the bill to dismantle the Commerce Department and privatize NIST to this series of hearings, and so he is not here, but maybe he has a staff person here, and we will be taking him to NIST, and others who are interested, to see the operation there.

Mr. Calvert?

Mr. CALVERT. I want everybody to relax here, because we are not proposing a 25 percent cut in NIST. As a matter of fact, we are increasing at least what I see on the proposed appropriation is an actual increase in NIST's budget process this year.

There are certain basic functions that government still needs to do, and we will go on delivering the mail and defending its shores, and I think that NIST is a very appropriate agency and I expect it will continue to be a part of this government.

I know the gentlelady from Maryland is going to fight hard to make sure that is exactly the case.

I have a couple of questions for you. PL has quite a number of CRADAs with industrial partners. I assume many of these and other NIST activities involve the development of intellectual property of commercial interest to industry.

How does NIST balance the desire of the industry partner for exclusive property rights with the government's desire to defuse that knowledge widely, especially when that knowledge is created with federal funds?

I guess, Doctor, you brought that up earlier. There's a series of questions here, but that was the first one.

Dr. GEBBIE. I think on the issue of CRADAs, there has been some misunderstanding about CRADAs throughout the Federal Government.

The National Institute of Standards and Technology has worked closely with industry since we were founded in 1901, using our interactions with industry to support our mission. In 1988 the whole idea of CRADAs simply formalized this relationship.

But everything that we do with industry is in support of our mission, and no separate funds are set aside at NIST, as they are in some other government agencies, specifically to support CRADAs.

I can give you one example of some work that we do in the Physics Laboratory with a consortium of about seven companies from the National Energy Institute, which is responsible for looking out for medical nuclear standards and the nuclear power industry standards.

Here they are working closely with us to provide standards for the radiopharmaceuticals that Dr. Paliwal mentioned are used in probably a quarter of all the patients who go into hospitals for a wide variety of diagnostic procedures.

This consortium has somebody working at NIST and has had for a long time with us to develop these standards which will then be available to everybody, all the manufacturers of radiopharmaceuticals.

So we work with industry only when it is supporting our own mission.

Mr. CALVERT. As you work with industry and you say it is only to support your own mission, but are there activities that NIST is involved in that you are duplicating any type of proprietary work on an ongoing basis with industry that it is already doing?

Dr. GEBBIE. No. We would not be duplicating any work that should be done in industry.

Mr. CALVERT. Does NIST receive any royalty income presently as a result of licensing NIST-generated intellectual property?

Dr. GEBBIE. We do receive royalty income. I am probably not qualified to answer that question in any detail.

Mr. CALVERT. I was just curious if it was a substantial amount of income.

Dr. GEBBIE. I believe it is not.

Mr. CALVERT. Is not. Thank you.

Thank you, Madam Chairwoman.

Mrs. MORELLA. I would now like to recognize Mr. Gutknecht for any questions he may have.

Mr. GUTKNECHT. Thank you, Madam Chairwoman.

To pursue what Mr. Calvert started with, we are not, this Subcommittee and the Full Committee, are not recommending any cuts for NIST. As a matter of fact, the numbers in fiscal year 1995 I think the total budget was $245.9 million; in fiscal 1996 the final agreed number was $259 million.

The Administration is requesting $271 million. I think this Subcommittee and the Full Committee are actually going to recommend to the rest of the Congress $280.6 million. That represents, if my arithmetic is correct, a little more than a 10 percent increase, not a 25 percent cut. That, in many respects, is a tribute to the Chairwoman of this Subcommittee.

I think we do agree that the work that you do is important.

I do have a couple of questions, and I would like to pursue something the Chairwoman started on the whole issue of mammography standards.

There was a recent article in The Washington Post that suggested that improved breast X-rays are actually causing more women to have mastectomies than maybe are otherwise necessary.

Given the increasing sophistication and sensitivity of medical diagnostics, I guess the question I would like to know is, how does the medical profession educate itself and its doctors? Or how can you interface with the doctors, or even medical technology companies to give them better information so that we are really doing what can and should be done?

In other words, some of the things you are learning are not necessarily being widely disseminated to practitioners or even companies that are producing medical technologies.

Is there something we can do better in terms of communicating to folks out in the field what you are learning?

Dr. PALIWAL. I think there are several mechanisms in place now since this Act that was passed. The American College of Radiology, the American College of Medical Physics, and the Radiological Society of North America have put together a substantial amount of audio/visual and other learning packages. That process is in place.

Actually, there is a certification process that is in place for a qualification of the people to perform these procedures so that the right type of people do the right procedure and make the right decision.

I think that process actually is evolving continuously and is the type of support I think that NIST provides which is also a very important part of that whole process.

Other than that, I think I am not here to pass a judgment because I am not a physician; I am a medical physicist. But I can tell you that there is a tremendous amount of activity that is going on in this area, and this area has been very much impacted by the standards that have been put together by NIST in calibration procedures.

Mr. GUTKNECHT. So you are satisfied that you are doing the best you can to get the information out to somewhere in the field that may not be interpreted properly?

Dr. PALIWAL. That is possible, depending on the individual. But the organizations involved in this industry are also doing a substantial amount of work to continuously update and have continuing education programs with CME credits, and so on. That mechanism is in place for people to use.

Mr. GUTKNECHT. Madam Chairwoman, if I could change subjects just briefly here, Dr. Gebbie mentioned the high social rate of return on NIST investments. You have talked about that.

Should the social rate of return, if you want to call it that, be one of the primary criterion for federal investment?

Dr. GEBBIE. No, I think—if you are referring to my written testimony that I had written a section on how we measure the results of what we do, that was simply one approach that we take, where appropriate, to try and get some assessment of the value of our services.

We use different mechanisms for assessing this in different areas of our research. That happened to be on some radiometric measurements, I think, that you are quoting, and that certainly is a useful number for some of our programs.

Mr. GUTKNECHT. Is there any way that you could predict whether there will be this social rate of return?

Dr. GEBBIE. We have a variety of ways of setting our priorities, and certainly attempting to do exactly that.

In our area, for example, of optical radiation measurements in which that impact study took place, we established in 1972 the Council for Optical Radiation Measurements, which has a membership of about 150 individuals representing industry, government, and some universities. Their mandate is to assess pressing national needs and future potential problems for us to address.

That is the way that we have—they make a survey about every five years and write a report not only of the national needs but they put them in priority order. We then address them in priority order. That is our way of assessing that we are addressing those issues that are likely to bring the greatest rate of return.

Mr. GUTKNECHT. I just want to close by saying, Madam Chairwoman, that I am one who thinks perhaps the Department of Commerce ought to be closed, but that does not necessarily mean that all of the functions that are currently under the umbrella of the Department of Commerce are not important.

Clearly, NIST is. That clearly is a Federal function. I think the budget numbers reflect the priority that we put on the work that you do.

I think where we get into this debate sometimes is where does clearly the government responsibility end and private responsibility begin?

We have had, in this committee and others, a rather healthy debate about the whole term of "corporate welfare." It does become a bit frustrating when we learn that millions of dollars are given to otherwise enormously profitable corporations to do research which, at least some people would argue, would have been done with or without the Federal money, but as long as the money has been there, you know, they are more than eager to accept it.

I think as we go forward I think it is going to be more and more difficult, particularly as we look at balancing the budget. You know, if you always do what you have always done, you will always get what you have always gotten.

So I just want to re-emphasize that the work that you do is important, and we thank you for coming here to testify today and we appreciate the work that you do, and please don't find yourself lumped into the debate about ATP and other corporate programs that have been a part of this Federal Government for a number of years.

Thank you.

Mrs. MORELLA. Thanks, Mr. Gutknecht. I want to thank you for the comments that you made about my chairwomanship, but I did want this group to know that the support for the NIST core comes from the subcommittee, not just me alone. It is universally shared and advocated.

I wanted to ask a question that deals with maybe the plethora of physicists coming out graduate school, and what do we do with them?

I know that you talked a little bit about that in your comments, Dr. Patel. I know the American Physical Society is looking into what to do, and I guess my question to you is. Should there be more like real-life experiences offered by places like NIST in terms of letting these people know what kinds of professions are available to them in that field.

Do you think NIST has a responsibility? And what can be done, directed to all of you.

Dr. PATEL. I think the issue of training and education for young physicists is a very important issue, as it is for many other disciplines, but it is especially so for physicists.

I believe, and many of my colleagues believe, that the present mode of training where the graduate student becomes a cloned replica of his or her professor is no longer an acceptable outcome.

One way of getting out of that conundrum is by requiring, not "making it available," but requiring that some part of the graduate student's life be spent working on real problems.

It is very easy for a faculty member—and I can wear both hats; I was in industry and now I am at the university--it is very easy for a faculty member to come up with a brilliant idea and apply it to what I will call a "toy problem"—it is not a toy problem, but it is a hypothetical problem that has no relationship with the real world, and its outcome will not change one way or another what the faculty member thought of the idea.

If on the other hand the graduate student were to be involved with NIST, or any other practical organization, he or she will immediately know whether that idea has any kind of any real merit or not.

So working on real problems, interfacing with real problems, gives one a way by which one can put a solid footing under one's foot—solid ground under one's foot, so that you can build the next level of technology or science.

I believe that is very important. One of the major, desirable outcomes from this kind of training provided by NIST would be that individuals will have a broader view of what physics is all about. It is not about doing your Ph.D. thesis over and over again; but, working on issues which are of national importance which are intimately tied with what I consider creation of wealth in the country, and creation of new jobs.

Mrs. MORELLA. Should NIST be doing more about that?

Dr. PATEL. I believe so, yes. I think there is, as you see from my written testimony, there is a lengthy description of both graduate student training, as well as post-doc's and visiting fellows.

I believe more of it would not hurt, but the question really is. Are there resources to be able to do that?

All of these activities are what I consider very importantly outreach activities. It allows NIST to diffuse its knowledge base and technology base widely, and make people aware of the fact that there are other things physicists, chemists, other disciplines can do.

Mrs. MORELLA. Dr. Paliwal?

Dr. PALIWAL. Well, actually I am a product of one of those applied processes from physics. We used to be considered second-class citizens in physics, but today we are not because we have better paying jobs than the regular physicists.

[Laughter.]

Dr. PALIWAL. Actually, if you look at the progression, if I may indulge, take two minutes of your time, my daughter just graduated from the University of Wisconsin with a degree in Physics Masters, and she went to her professor and advisor and asked what she should do.

He said, you should go for a Ph.D. degree. Then she had the nerve to ask him, then what would I do after that? And then he said, drive a cab.

[Laughter.]

Dr. PALIWAL. Now the point is that there are many other applied fields of physics that are growing now, and even the American Institute of Physics has started a section called Industrial Physics.

I represent medical physics. Even in medical physics, there are about a half a dozen branches. Though I am representing this American Association of Medical Physicists today, but the subspecialty is so wide that I cannot really define each of the technology bases. I am in a very specialized area in radiation therapy.

That is, I think, the answer to your question; but it doesn't have to be limited to medical physics. There are other technology- related industry-related physics with knowledge-based jobs that would be created if we support the basic education in physics and motivate and direct them to an identified area.

Mrs. MORELLA. Dr. Gebbie, would you care to comment on that?

Dr. GEBBIE. I would just comment that we work with students and post-doctoral research associates in support of our mission to provide the measurement infrastructure for the United States.

I think we do have an important effect on these students and how they work afterwards, but education is not our primary responsibility. That is the primary responsibility of the universities.

I think that to the extent we can work with them to persuade them to broaden their education is probably where our efforts are best put.

Mrs. MORELLA. It is a good point that they have a responsibility in this also, because I think that NIST should be offering maybe even more, as you say, according to what the resources will allow, but more of these opportunities for them.

I sometimes am confronted if I am speaking to a group who are involved in science in some way when a young person says. I have my degree in engineering, let's say, and I can't find a job; or physics.

Something is going wrong when you are then also trying to encourage young people, particularly women and minorities, to get involved in these fields and you are confronted with that kind of question.

Dr. GEBBIE. I believe we actually need more physicists, not fewer. We need them in Congress, and we need them in medicine, and we need them in law, and we just—I think it is a wonderful training; we just need to expand their horizons a little bit.

Mrs. MORELLA. We need to talk about background. I mean—and that is helpful in background. I am thinking of a paying job for them.

Incidentally, we did invite Congressman Ehlers, too. He knew we had the hearing, and we invited him to come as the physicist. He said, well, I know what they're doing, and everybody has conflicts.

Dr. PATEL. If I may mention an interaction I had recently with a small company in Los Angeles. It is a medical instrumentation company.

I was giving a talk at EMGEN, which is a very large drug manufacturing company. But this individual walked up to me and said, what's wrong with physicists?

I said, I'm sorry? What do you mean by that?

He says, I've been trying to hire physicists in my company for the last six months and nobody wants to apply.

The key point is that here is an organization which employs perhaps 10, 12 physicists. It is a medical device company. And the principal problem there is that anybody who comes there cannot redo his Ph.D. thesis over and over again. The person has to learn something new.

I think, as Dr. Gebbie pointed out, there are several issues we need to address. Education is part. Training is another part. I think there is a lot to be done there.

Mrs. MORELLA. And connecting the two is another part.

The NRC panel noted excessive turnabout times for some physics laboratory measurement and calibration services for industry.

Should the Institute be providing such services?

Does anybody want to comment on that?

Should they be accredited private sector labs that offer those services?

Dr. GEBBIE. We do provide the highest level service.

There are indeed secondary laboratories. We have a whole network of hospitals that provide ionizing radiation standards at the secondary level, but we are the primary standard to which all of these must legally be traceable.

Mrs. MORELLA. How does NIST work with these private- sector labs?

Dr. GEBBIE. Depending on the particular sort of standard, they will send—they will package up their volt meters, and send them to us. We will then calibrate them—voltage actually is another laboratory but—and send them back so that they then can be used as their primary standards with which to calibrate other volt meters.

Mrs. MORELLA. Dr. Paliwal?

Dr. PALIWAL. Just to elaborate on what Dr. Gebbie said, that there are two processes, one is a routine service, standardized, that can be done. Second is a primary standard activity. Whenever the demand in the market is big, when it becomes routine, NIST has created in the past secondary labs that would do that kind of activity on a fee-for- charge basis. But the primary traceability still has to go back to NIST.

An example of these is the ionization chamber for radiation therapy therapy facilities; or mammography KVP meters, and things like that. So they do respond to the market needs, and they keep those two issues also out so that they don't become a mundane operation activity, but they let the market take place by creating the secondary lab.

Mrs. MORELLA. Thank you.

I just wondered, is there any final comment that any of you would like to make before I adjourn the first panel?

[No response.]

Mrs. MORELLA. Well I want to thank you very, very much for your expertise and your written statement—oh, Mr. Brown has just joined us now, so perhaps I will let him do the wrapup on this first panel.

I was just about to thank them, Mr. Brown.

Mr. BROWN. I understand, Madam Chairwoman. You are unfailing gracious to me because of my old age, I guess——

[Laughter.]

Mr. BROWN. (continuing) —more than anything else.

I do not want to continue with this panel, because I know we have another panel, but if I could just ask one question. I understood there was some discussion of the Advanced Technology Program while I was away.

I am concerned with the interaction between that program and the Core Labs. Could you just tell me very briefly the degree to which the labs provide services or receive funding from the ATP program in connection with their mission?

Is that something you could quickly respond to?

Dr. GEBBIE. I think there is a complementary relationship between the laboratories and the Advanced Technology Program.

ATP provides one additional window for us on the needs of industry, and they can come to us to provide the sort of generic measurement technology that is needed to support some of their award programs.

Mr. BROWN. And when they do that, do they provide any reimbursement or revenue flow to your labs, for example?

Dr. GEBBIE. There is some support for this generic work that has come from the Advanced Technology Program.

Mr. BROWN. Well thank you very much for that response.

Thank you, Madam Chairwoman.

Mrs. MORELLA. Again I thank the members of this panel. You have been terrific. Thank you for your time, your expertise, written statements, and responses to the questions, Dr. Gebbie, Dr. Patel, and Dr. Paliwal.

Now we will have the second panel come forward:

Dr. Hratch Semerjian, who is the Director of Chemical Science and Technology Laboratory at the National Institute of Standards and Technology; Dr. Isiah Warner, who is the Chair of the National Research Council Board on Assessment of NIST Programs on the Panel for Chemical Science and Technology; and Dr. Rita Colwell, the President of the University of Maryland Biotechnology Institute, University of Maryland.

I want to welcome you. This is our second panel, which is one of two hearings we are having particularly for the record so it will be known what is done at NIST, and this panel is on the Chemical Science and Technology Laboratory.

I think, my friends, you will not weep if we can wind this up at noon. Wouldn't that be neat? I have a couple of meetings, and I know you do, and I do want you to know that all Members of the Subcommittee and the Full Committee are given copies of your testimony, and it is of course in the permanent record.

So perhaps we will start off with Dr. Semerjian.

STATEMENT OF DR. HRATCH SEMERJIAN, DIRECTOR, CHEMICAL SCIENCE AND TECHNOLOGY LABORATORY, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

Dr. SEMERJIAN. Thank you, Madam Chairwoman.

Mrs. MORELLA. Thank you.

Dr. SEMERJIAN. And Congressman Brown.

I am very pleased to be here to discuss our programs that provide the measurement infrastructure required to enhance the U.S. industry's productivity and competitiveness, ensure equity in the domestic and international trade, and improve our Nation's standards of health, safety, and environmental quality.

In the Chemical Science and Technology Laboratory, we perform three essential and unique functions for the Nation.

First and foremost, CSTL provides the fundamental basis for the Nation's measurement system in chemistry, chemical engineering, and biotechnology.

We provide standard reference materials and calibration services that ensure traceability of measurements to the national and international standards.

CSTL also provides accurate and reliable information in the form of data and predictive tools to industries where chemistry matters, such as in the biotechnology, chemical, petrochemical, and semiconductor industries.

This information is essential for design and implementation of chemical processing and other manufacturing systems.

Finally, we partner with industry and participate in professional organizations to identify and address the next generation measurement needs of the U.S. industry.

I would like to tell you about one particular activity in our laboratory to give you a sense of the nature and impact of our work. This is a topic that is near and dear to our heart—namely, cholesterol measurements.

I have prepared a display here to show the important role that measurement accuracy plays in the determination of heart disease risk, and pivotal role CSTL has played in ensuring the accuracy of cholesterol tests.

[Chart shown.]

According to a 1994 GAO Report, the measurement on certainty for cholesterol was over 20 percent not too long ago. Such large measurement uncertainties meant that a substantial number of patients might have been misdiagnosed as either not needing treatment when they indeed do, or needing treatment when in fact they did not. Neither result is good for either the patient nor the health care system in general, resulting in either costly but unnecessary treatment, or a higher risk of hospitalization or death.

Our laboratory got involved in this cholesterol measurement problem as the result of a request we received from the College of American Pathologists. This is a clinical measurements trade organization that annually tests measurement accuracy of over 18,000 clinical laboratories.

Our research produced high-accuracy measurement methods that were used to develop standard reference materials for cholesterol, some of which I have here, provided to the laboratories in these vials.

These test materials are used by commercial laboratories to verify their measurement accuracy. As noted in the report, development of NIST Standard Reference Materials has been a significant factor in improving clinical cholesterol measurements in the past 20 years, resulting in a reduction in measurement uncertainty almost by a factor of 4.

This improvement may save over $100 million per year in physician and hospital health care costs in the U.S.

Because of the infrastructural nature of our work, CSTL serves a very broad constituency of small and large businesses, as well as other government agencies and the scientific community in general.

CSTL fulfills a critical and unique role in enhancing the U.S. industry's competitiveness by providing the measurement tools and information needed to improve manufacturing efficiency and product quality.

Madam Chairwoman, I thank the Subcommittee for the opportunity to describe some of our laboratory activities. I have submitted a more detailed statement for your information, and I will be happy to answer any questions you may have.

Thank you very much.

[The prepared statement of Mr. Semerjian follows:]

STATEMENT OF HRATCH G. SEMERJIAN

DIRECTOR

CHEMICAL SCIENCE AND TECHNOLOGY LABORATORY

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

BEFORE THE

SCIENCE SUBCOMMITTEE ON TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

MAY 2, 1996

Madam Chairwoman and Members of the Subcommittee. I am Hratch Semerjian, Director of the Chemical Science and Technology Laboratory (CSTL) at the National Institute of Standards and Technology (NIST). I am pleased to be here to discuss the programs in CSTL that provide the measurement infrastructure required for enhancement of U.S. industry's productivity and competitiveness, assurance of equity in domestic and international trade, and continued improvement of our nation's high standards of health, safety and environmental quality.

Chemical and physical measurements play a significant role in the success of U.S. industry and the quality of our daily lives. The cost of your fuel bill, the accurate diagnosis of heart disease, or that new car with an air conditioner that does not use materials that are believed to destroy the earth's ozone layer, are all examples where measurements and measurement standards play a key role. Our laboratory has provided research and measurement services significantly improving all of these areas. Today, I hope to bring some of our specific measurement activities into focus, and articulate the essential role of the federal government in developing and disseminating chemical measurement technology.

The mission of the NIST Laboratories is to promote the U.S. economy and public welfare by providing technical leadership for the nation's voluntary system of measurement and standards infrastructure, and by assuring the availability of needed measurement capabilities. Our laboratory efforts are planned and implemented in cooperation with industry, and are focused on infrastructural technology. The benefits of such enabling technologies typically spread across entire industries, and the investment needed to produce them cannot be recovered by individual companies. To fulfill the NIST mission, the Chemical Science and Technology Laboratory has established three major goals for itself:

(1) to establish CSTL as the pinnacle of the traceability structure for measurements and standards in chemistry, chemical engineering and biotechnology, and provide the fundamental basis of the nation's measurement system;

(2) to assure that U.S. industry has access to accurate and reliable data and predictive models needed to determine the chemical and physical properties of materials;

(3) to anticipate and address next generation measurement needs of the nation, by performing cutting-edge research in chemical measurement science.

Measurement Traceability

To meet our first goal, we provide standard reference materials and calibration services that ensure the traceability of measurements to national standards. During FY95, CSTL developed 34 new Standard Reference Materials (SRMs) for use in technology areas such as industrial process control, environmental monitoring, clinical measurements, food and nutrition labeling, materials characterization, DNA fingerprinting, and automotive catalyst recycling.

One important series of SRMs I would like to mention specifically are those used in the measurement of cholesterol. Many of you may actually know your latest cholesterol reading. The accuracy of that reading is important for your physician to predict the risk of heart disease and, if necessary, prescribe preventive measures. NIST has played and continues to play a pivotal role in assuring the accuracy of cholesterol measurements.

We have established and maintain three major mechanisms for assuring accuracy of cholesterol measurements. First, we have developed several standard reference materials which are used to assure reliable and accurate determination of cholesterol values. These SRMs are used by instrument companies to validate their equipment and procedures as well as by commercial clinical laboratories to validate their results and methods. Secondly, we have developed high-accuracy reference measurement methods that NIST has rigorously validated. These methods can be replicated by researchers who need to validate their new measurement technology on a wide range of blood samples. And finally, we collaborate closely with the College of American Pathologists (CAP), the premier clinical measurement testing and quality assurance organization (see Attachment 1 for a list of acronyms). The CAP provides an array of proficiency samples to over 18,000 U.S. clinical laboratories and uses them for testing of measurement accuracy. The CAP has established a reference laboratory at NIST and maintains three full-time technical staff at NIST who collaborate with our staff to develop reference materials for measurements such as cholesterol.

Attachment 2 provides a graphical representation of the pivotal role NIST has played in improving and assuring cholesterol measurement accuracy. According to a 1994 General Accounting Office Report (GAO-PEMD-95-8), the measurement uncertainty for cholesterol was over 20% not too long ago. Such large uncertainties mean that a substantial number of patients might be misdiagnosed as either not needing treatment when they do or needing treatment when in fact they do not. Neither result is good for the patient, resulting in either costly treatment or a higher risk of death. Such large measurement errors also affect the health care system, where the total cost for cholesterol-lowering therapy may be as much as $1500/year for each patient. The cost of not treating is even higher, because of the high price of in-hospital treatment of heart attacks and strokes. Reducing the measurement uncertainty from 18% in 1969 to 5% in 1995 - may save over $100 million per year in physician and hospital health care costs.

We all know that it is important to measure the relative levels of the “good” HDL cholesterol versus the “bad” LDL cholesterol. In the coming year, we are partnering with the Mayo Clinic and CDC to develop reference materials for HDL and LDL cholesterol. We will also continue the development of definitive methods and SRMs for other clinical diagnostic markers such as thyroxine (for thyroid function), bilirubin (for liver function), cadmium, arsenic and lead (for toxicity).

Another essential CSTL activity is to provide calibration services, where a direct link of traceability is established between a customer's instruments and national primary standards of measurement. During FY95, CSTL provided over 1100 calibrations for more than 500 companies of all sizes. In order to produce competitive, high-quality, and low-cost products, the U.S. manufacturing industry must have accurate and traceable measurements of pressure, vacuum, volume, flow rate, temperature, humidity, etc. These measurements ensure equity in trade - exchange of goods at a fair price - and production processes that maximize output and product quality, as well as minimizing their environmental impact. As an example, CSTL maintains facilities to provide temperature calibrations to U.S. industry, government agencies, and academia. The need for accurate temperature measurements is obvious in such wide-reaching areas as metallurgical furnaces, residential uses, food processing, jet engines, semiconductor manufacturing, chemical and materials manufacturing, and medical applications. Each year CSTL calibrates over 500 temperature-measuring instruments, ranging from liquid-in-glass thermometers to high-temperature thermocouple devices used in industrial applications. Over 100 million new thermocouples are put into service each year in the U.S. Recently published NIST Monograph 175, which was compiled as part of an international cooperative effort, contains reference functions for all industrially important thermocouples types and forms the basis for all these measurements.

An increasingly important role for CSTL is ensuring the international acceptance of U.S. standards and measures for trade. As other nations lower the traditional tariff barriers for U.S. products, new technical barriers for trade are being established. In order to export their products, U.S. industries are increasingly required to demonstrate conformity with international quality assurance regulations. All such conformity assessments require measurement traceability - an unbroken chain of measurement links to national or international standards. CSTL is working closely with several international standardization organizations such as EUROMET and NORAMET to assure that U.S. standards and measurements in chemical technology are accepted for compliance with international standards and regulations. To achieve acceptance of U.S. standards, we compare our measurements with those of other nations to establish comparability and traceability. We have made significant progress in this process within our regional standards group, NORAMET, established as an outgrowth of the NAFTA legislation. We are also working with NMi, one of the key members of EUROMET to establish comparability of our gas standards.

Accurate and Reliable Chemical Information

The second CSTL goal is to provide accurate and reliable information on the properties of materials needed by the industrial and academic community for design and implementation of chemical processing systems. To accomplish this goal, the laboratory develops reference data and predictive computational models to describe the chemical and physical properties and behavior of chemical compounds. CSTL provides reliable, high quality chemical data by either evaluating existing data or by direct experimental measurement when suitable data do not exist. Important CSTL contributions include databases on chemical thermodynamics, chemical kinetics, protein crystallography, thermodynamic properties of biomolecules, thermophysical properties of industrially important fluids, and spectroscopic properties of chemical compounds. One of the most heavily used CSTL databases is the NIST Mass Spectral Database (see Attachment 3). This powerful software allows the direct identification of chemical compounds important to chemical manufacturing, medical research, and environmental monitoring. Two thirds of all mass spectrometers manufactured in the U.S. include this powerful database.

Another CSTL database provides information on the properties of refrigerants and alternatives to currently used chlorofluorocarbons (CFCs). The U.S. has agreed, as part of the Montreal Protocol, to stop production of CFCs by the end of 1995, and intermediate replacements (hydrogenated CFCs) by the year 2030. CFCs have been, until recently, used in production of $28 billion worth of new goods and services per year. In addition, there are about $350 billion worth of installed equipment (refrigerators, air conditioners, cars, industrial systems, etc.) currently using CFCs. In order to maintain its market share in the refrigeration business, it was of utmost economic importance for U.S. industry to rapidly identify suitable replacements for CFCs that could be used in existing equipment and processes, as well as in newly designed systems. CSTL has played a vital role in providing the chemical information required to identify a new set of viable refrigerant fluids for commercial production (see Attachment 4). Data compiled by CSTL staff have been widely disseminated, using all available distribution mechanisms. We have distributed over 750 copies of the computerized database REFPROP (Refrigerant Properties), which provides properties of 43 pure compounds and their mixtures. Some of the NIST data are also included in the ASHRAE Handbook of Fundamentals, which is distributed worldwide to more than 50,000 refrigeration engineers and designers. Results of NIST work have been selected as the *de facto* international standard.

Research on Measurement Science

CSTL also performs scientific research to achieve our goal of anticipating and addressing the future measurement needs of the U.S., identified in partnership with industry. Advancing the field of measurement technology will have an increasingly important effect on U.S. industrial productivity, since detailed chemical and physical measurements are becoming a critical element of low-cost, high-quality manufacturing processes. Historically, accurate control of manufacturing processes, such as the production of semiconductors, has relied only on measurement parameters like pressure and temperature which may be used as indirect indicators for process control or product quality. CSTL has supported the accuracy of those traditional measurements. However, future manufacturing will require the real-time monitoring of the actual chemical composition of process streams and products with devices such as solid state sensors. Anticipating this need, CSTL began research almost ten years ago on the basic chemistry and material science of gas sensors capable of monitoring chemical composition. Working with the Electronics and Electrical Engineering Laboratory at NIST, we have developed a device, with an array of sensors with individual temperature control, that can monitor a mixture of gases such as those found in semiconductor manufacturing. The ACS publication, *Chemical and Engineering News*, published a description of this exciting new sensor technology last month (see Attachment 5). CSTL researchers have obtained three patents on these "hot plate" sensors and have had more than 25 companies show interest in licensing this state-of-the-art measurement technology. The interest in these and other new technologies demonstrates how important it is that CSTL maintain its efforts to anticipate the measurement needs of its industrial customers.

To achieve our role as the nation's technology leader in chemical measurement, we maintain advanced technical facilities and a highly trained scientific staff. Last year, the CSTL staff consisted of about 350 chemists, physicists, engineers, biologists, computer specialists and support personnel. Because of the highly technical nature of our work, 90% of our staff are scientists and engineers, with only 10% of the staff providing administrative support. In addition, we have more than 250 guest researchers from industry, universities and other national standards laboratories, a number nearly as large as our permanent staff.

As the nation's reference laboratory, CSTL provides services to a very broad constituency. We support measurements in the biotechnology, chemical manufacturing, petrochemical, instrument manufacturers, energy, semiconductor, pharmaceutical and transportation industries. CSTL works closely with both large and small U.S. companies. For example, we are working with large producers, such as SmithKline Beecham Pharmaceuticals, on membrane biosensor technology. Small companies, such as Life Technologies, Inc., depend on our DNA identification standards for quality assurance of their human identification services. We work with our industrial clients in mature measurement technologies, such as in temperature measurement, and also in emerging areas in biotechnology, providing data on protein crystallography. In addition to providing essential measurement services, we often work directly with companies to develop and transfer technology through Cooperative Research and Development Agreements (CRADAs). NIST has a streamlined process for establishment of CRADAs requiring less than a month for approval. CSTL currently has 27 CRADAs with large corporations, 23 with small emerging businesses and 5 with public organizations. For example, we have a CRADA with IBM to develop advanced computing technology for protein crystallography. A small business, Nitrate Elimination Company, is working with CSTL researchers to develop generic technology for the construction of enzyme-based electrochemical biosensors. We are also working with the American Red Cross on technology for the chromatographic purification of blood proteins.

To anticipate and address the next generation of measurement needs of the nation, it is critically important for us to assess future technology developments. Our participation in professional societies and voluntary standards organizations provides a window to major technological developments and the measurements required to support those developments. CSTL staff hold 460 committee memberships in major technical trade organizations. Working on the CMA/ACS/AIChE/CCR Roadmap for the Chemical Industry helps us identify major technological trends into the next century. The AIChE Design Institute for Physical Property Data (DIPPR) provides us with valuable information on future needs of the chemical industry for properties data. Interactions with industrial standards organizations such as ASTM helps us identify reference materials and calibration services needs. Our participation in NCCLS is critical for identifying the need for future clinical standards and measurements.

As we address national measurement problems, we actively seek feedback from our measurement services customers. Although income from standard reference materials and calibration services account for only about 15% of the CSTL operating budget, the direct customer interaction provides an opportunity to evaluate the quality of CSTL services and serves as a conduit for articulating new measurement needs. For example, CSTL provides flow calibration services for gases such as those used in semiconductor fabrication. One factor in the continued success of the U.S. semiconductor industry is directly related to their measurement capability on the manufacturing line. A fabrication line often has several thousand mass flow sensors that require accurate calibration in an intermediate flow range. CSTL maintains traceability for these sensors by providing calibration services for test equipment vendors and through round robin measurement comparisons. Recently, we learned from our calibration customers that in order to manufacture the next generation of semiconductor devices, accurate measurements over a thousand times wider flow range will be needed. CSTL researchers are currently developing primary and transfer standards for this wider range of flow rates, providing the infrastructural measurements that the U.S. semiconductor industry needs to maintain a competitive edge in the international marketplace.

Finally, other government agencies identify technical issues of national importance and look to CSTL for research on advanced measurement methods, for development of new standard reference materials and to provide and manage quality assurance programs. CSTL received about 20% of its operating budget from such other agency agreements last year.

In summary, CSTL activities play a critical and unique role in enhancing the competitiveness of U.S. industry by providing them the infrastructural tools needed to improve process efficiency and product quality.

As the nation's primary reference laboratory for chemical measurement technology, CSTL provides the traceability structure for measurements and standards in chemistry, chemical engineering, and biotechnology and provides the fundamental basis of the nation's measurement infrastructure. Measurements and standards traceable to NIST ensure equity in domestic trade and help guarantee access for U.S. business to foreign markets. CSTL assures that U.S. industry has access to accurate and reliable data on the chemical and physical properties of materials. Industry needs this information to design and accurately control manufacturing processes, resulting in higher quality products made at lower cost with minimal environmental impact. By performing cutting-edge research, we anticipate and address the next generation of measurement needs of the nation. This infrastructural measurement research helps provide the basis for U.S. scientific and technological leadership.

Madam Chairwoman, I thank the Subcommittee for the opportunity to describe our laboratory activities. I will be happy to answer any questions you may have.

Attachment 1

List of Acronyms

ACS	American Chemical Society
AIChE	American Institute of Chemical Engineers
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
ASTM	American Society for Testing and Materials
CAP	College of American Pathologists
CCR	Council for Chemical Research
CDC	Centers for Disease Control and Prevention
CFC	Chlorofluorocarbons
CMA	Chemical Manufacturers Association
CRADA	Cooperative Research and Development Agreement
CSTL	Chemical Science and Technology Laboratory
DIPPR	Design Institute for Physical Property Data
DNA	Deoxyribonucleic Acid
EUROMET	European Metrology Organization
GAO	General Accounting Office
HDL	High Density Lipoprotein
LDL	Low Density Lipoprotein
NAFTA	North American Free Trade Agreement
NCCLS	National Committee for Clinical Laboratory Standards
NIST	National Institute of Standards and Technology
NMi	Netherlands Measurement Institute
NORAMET	North American Metrology Cooperation
REFPROP	Refrigerant Properties Database
SRM	Standard Reference Material

Attachment 2

Improved Cholesterol Measurement Accuracy Saves Health Care Dollars

NIST Contributions to National Reference System for Cholesterol

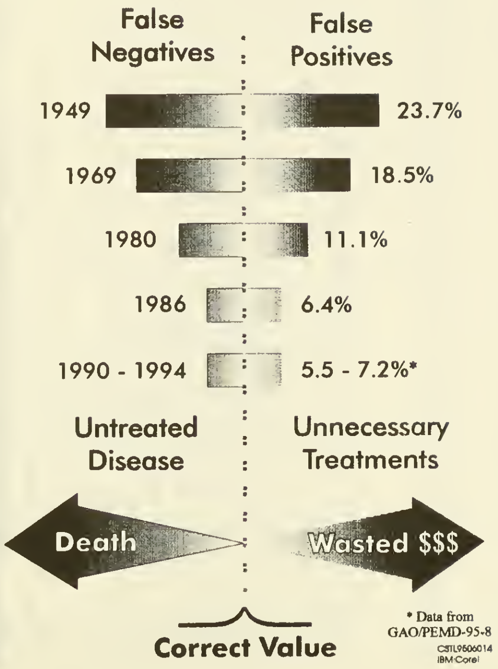
1967 - SRM 911
Pure Cholesterol

1980 - Definitive Method for
Serum Cholesterol
1981 - SRM 909 Cholesterol
in Human Serum

1988 - SRMs 1951 & 1952
Cholesterol in Serum

Future - Methods & SRMs for
HDL & LDL Cholesterol

Improvement in Uncertainty from 1969 to Present Level ***May Save $100M/year*** Unneeded Treatment Costs

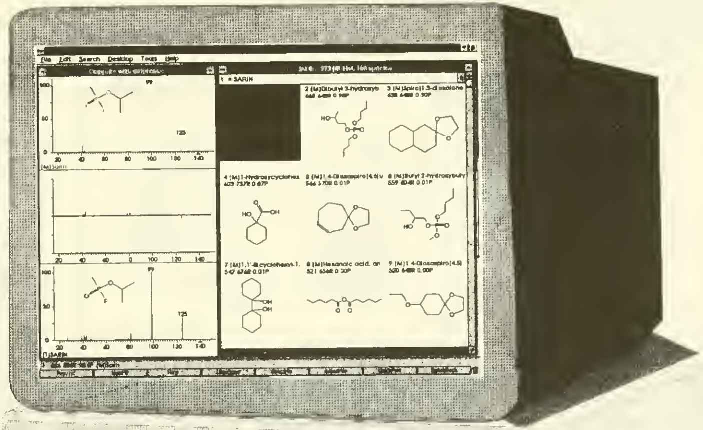


* Data from
GAO/PEMD-95-8

CSTL9506014
IBM·Corel

Attachment 3

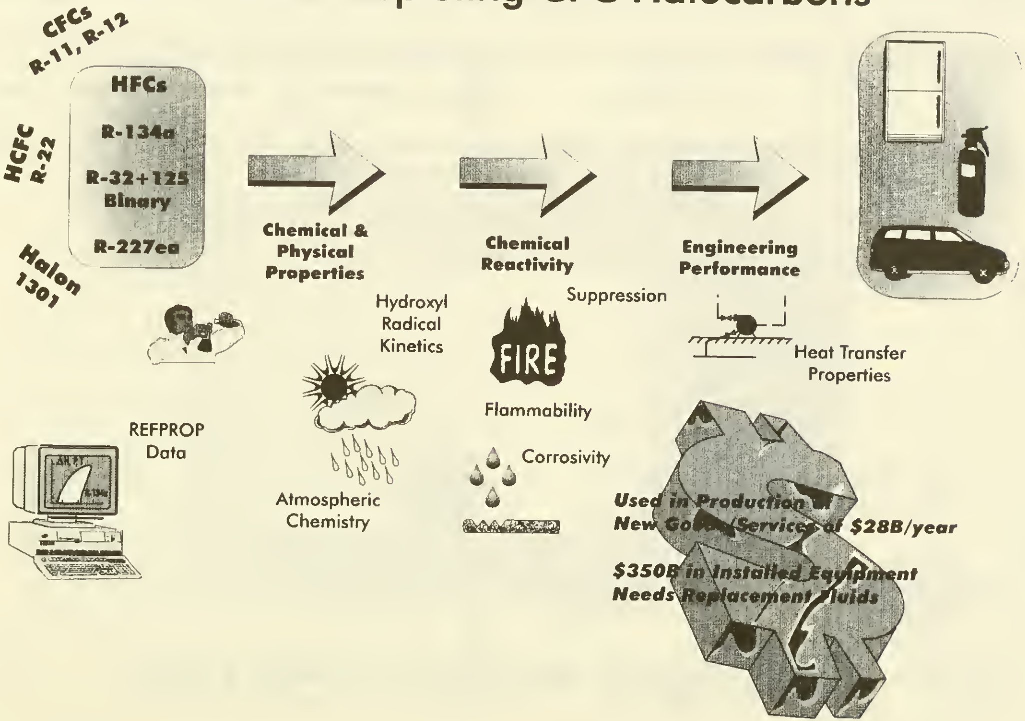
NIST Mass Spectral Database



- Identifies compounds of industrial, health and environmental importance from a library of > 62,000 entries
- Soon to include all commercially-available chemicals
- Over 60% of the 3000 Mass Spectrometers/yr sold in U.S. are sold with the MS Database, a $200M industry
- Latest "Dynamic Link Library" and "Windows" versions released

Attachment 4

Environmentally-Safe Replacements for Ozone-Depleting CFC Halocarbons



CFCs R-11, R-12

HCFC R-22

Halon 1301

HFCs

R-134a

R-32+125 Binary

R-227ea

Chemical & Physical Properties

Chemical Reactivity

Engineering Performance

REFPROP Data

Hydroxyl Radical Kinetics

Atmospheric Chemistry

Suppression

Flammability

Corrosivity

Heat Transfer Properties

Used in Production of New Goods/Services of $28B/year

$350B in Installed Equipment Needs Replacement Fluids

GOVERNMENT

Attachment 5

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NIST Chemistry Labs Are Evolving To Meet Changing Needs Of Science

■ ***Chemical Science & Technology Laboratory provides comprehensive research data for industry, other federal agencies***

David J. Hanson, C&EN Washington

Competing in the world marketplace is the mainstay of today's modern chemical industry. Being successful in that market requires a serious commitment to research, product quality, and high standards. And it is the National Institute of Standards & Technology (NIST) that makes sure industry has the standards to ensure quality.

NIST has evolved into a complex organization since its founding in 1901 as the National Bureau of Standards. Headquartered in the Washington, D.C., suburb of Gaithersburg, Md., with facilities also in Boulder, Colo., NIST employs about 3,200 scientists, engineers, and technicians and a large number of visiting researchers. Its standards and research function is centered in its laboratory programs, of which one of the biggest and busiest labs is the Chemical Science & Technology Laboratory (CSTL).

CSTL is unique. It is the world's most comprehensive facility for chemical and physical measurements and standards, for all kinds of chemical databases, and for predictive models. The laboratory has customers in nearly every industrial sector of the economy and works with many other federal agencies, helping them meet their regulatory goals. It performs cooperative research with industry under several programs and ensures international comparability of U.S. measurements with those of other nations.

CSTL's budget is around $50 million per year, but only about half of that comes directly from congressional appropriations, according to its director, Hratch G. Semerjian, a Ph.D. engineer. NIST generates considerable revenue from selling its products. In fiscal 1995, NIST garnered $9 million from selling standard reference materials, $2.2 million from the sale of standard reference databases, and $5.1 million for performing instrument calibrations. CSTL is responsible for about 60%, or nearly $10 million, of this income. The laboratory employs 122 chemists and 93 other scientists and engineers, as well as technicians and other support staff.

In addition to the funds from reference materials and database sales, CSTL is reimbursed for the work it does for a variety of other government agencies, including the Environmental Protection Agency, the National Oceanic & Atmospheric Administration, the Centers for Disease Control & Prevention, and the Department of Justice. In this period of budget tightening, Semerjian says, CSTL is trying to lessen its dependence on funds from other federal agencies. These agencies may not be able to pay for as many services as they have in the past, but more importantly, CSTL wants to be sure its priorities are driven by industry's needs.

This year, like many other federal agencies, NIST's work was disrupted because of the government shutdowns caused by the budget impasse between Congress and President Clinton.

The lab has just about recovered from the shutdown, Semerjian says, but he is concerned about the long-term effects it will have on CSTL programs. "What worries me is how this affects our staff retention and recruitment," he says. One immediate bad sign is a 20% drop in the number of applications normally received for CSTL postdoctorate positions. "I'm sure that is because of the furlough and the uncertainty—people not knowing if they want to work somewhere with that problem," he says.

Problems or no, CSTL is an interesting place. "There have been lots of evolutionary changes in the chemistry labs over the years," explains Semerjian. "It is a quite dynamic area, and we have had to change as the necessities of science change." Some areas that have become increasingly important in recent years include measurements for pollution prevention, DNA profiling, and conforming with international standards.

But perhaps the first thing one thinks of with regard to NIST and chemistry is the development and certification of standard reference materials. Much U.S. industry production and international trade depends on accurate measurements. To be accurate, there must be a standard from which the measurement derives and a method to measure that standard accurately. CSTL offers a wide range of reference materials for chemicals—including ferrous metals, high-purity materials, fossil fuels, geological materials, and ores—and for environmental, health, and clinical laboratory measurements. And it develops

Collaboration leads to high-sensitivity, micromachined hot-plate sensor

Researchers at the National Institute of Standards & Technology's (NIST) Chemical Science & Technology Laboratory (CSTL) not only have to make accurate measurements, but frequently have to invent the measuring tool.

The quantitative measurement of gas concentrations in mixed atmospheres is important in many manufacturing processes, as well as medical diagnosis and environmental monitoring, but existing sensors suffer from poor detection specificity and can be expensive. Research among CSTL and several collaborators over the past several years now offers a solution.

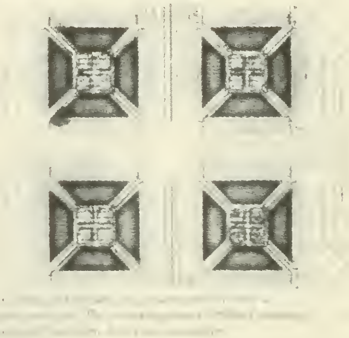
The CSTL device consists of an array of microsensors atop a semiconductor chip. Each tiny microsensor has a heating element and metal oxide sensing film that produces a response that allows detection of different gases and their concentrations. Differing thermal kinetics of adsorbate-metal-oxide reaction chemistry explain the ability of the individual pixels on the semiconductor to respond to different gases.

Arrays of microsensors are needed because individual sensing components are not perfectly selective and have a range of sensitivities to mixtures of gases. When the responses of each sensor are understood, both singly and in combination, NIST scientists are able to sort out the response patterns, deriving data on individual gas concentrations.

Rapid pixel heating and cooling is a key to their optimal performance. Adsorbed gas concentrations on metal oxide sensing surfaces can be changed in about 3 milliseconds. Temperature programming of these micro-hot plates is used to heat the pixels from ambient temperature up to 500 °C. They then quickly cool and a pixel's electrical resistance is measured. Heating cycles can also be used to clean the pixel of adsorbed gases.

A complete sensor would use an array of pixels with different sensing films operating with temperature-varying programs that could be adjusted as needed. The responses would be analyzed employing specific algorithms to chemically identify specific gas species.

NIST scientists and their collaborators have been able to get significantly different responses to ethanol, methanol, acetone, and formaldehyde with the experimental devices. The sensors also demonstrate a quantitative response to carbon monoxide in air at concentrations between 3 and 1,000 ppm.



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Eventually, a credit-card-sized device with the micro-hot-plate sensors, detectors, and a microprocessor will be used in industrial process control, environmental monitoring and pollution prevention, or medical diagnostics.

NIST is collaborating on this research with scientists at the University of Maryland and the Department of Defense's Microelectronics Research Laboratory. CSTL staffers are also collaborating with an industrial umbrella group called the American Industry/Government Emissions Research Consortium, which includes the major automobile manufacturers, the California Air Resources Board, and the Environmental Protection Agency.

state-of-the-art methods for making accurate measurements.

As an example, Semerjian offers the development of a standard reference material to determine the amount of rhodium in automobile catalytic converters. "Because the small amount of rhodium in these is very valuable, if your measurements are not very good, say, only to about 10%, you could lose your shirt," he says. Previous measurements were only accurate to about 6%, but NIST standards provide 1% or better accuracy for rhodium. "By developing this standard reference material, we've improved a company's ability to determine rhodium levels and to calibrate its instruments. And we provide it in the correct environmental matrix," Semerjian adds.

The U.S. auto industry uses more than $500 million per year in precious metals (platinum, palladium, rhodium), so being able to recover the metals completely is significant. Transfer of this technology to industry was facilitated by a cooperative research and development agreement (CRADA), a tool CSTL uses frequently. With 65 active CRADAs last year, CSTL was second only to the Materials Science & Engineering Laboratory at NIST in the number of agreements with industry and universities.

Semerjian notes that there is a growing demand in industry for the kinds of reference materials CSTL produces. But, he says, "we certainly cannot meet the entire demand. We are a research lab, not a production plant. What we are doing is developing the standard reference material so that other companies can manufacture what are called secondary reference materials to sell. These have lower accuracy—or more uncertainty—but still are perfectly good for practical applications."

NIST's standard reference data program makes nearly 100 computerized databases and compilations available. Many of these come from the chemistry laboratory. The importance of having reliable databases in chemical science cannot be underestimated, and NIST produces compilations on analytical chemistry, biotechnology, kinetics, materials properties, surface data, thermodynamics, and more.

One program that has had a large impact is the compilation of the mass spectral database. Begun just a few years ago, this NIST product comes installed on more than 60% of mass spectrometers, or about 4,000, sold in the U.S. It identifies more than 62,000 compounds of industrial, health, and environmental importance and is being updated so that it will contain spectra for almost all commercially available chemicals. Just this year, a more user-friendly version of the database was released. It has new automatic searching capabilities and identification aids. CSTL sorts through mass spectral data from all over the world to be sure it uses only the most complete and reliable data, "from the West Coast of the U.S. all the way to Novosibirsk in Siberia," Semerjian says.

Other significant chemical databases available from CSTL include an expanded database for chemical kinetics, one that holds information on 29,200 rate constants and 4,400 compounds, and another that holds information for modeling chemical reactions in solutions. Another database is available for predicting the thermochemical performance of materials. According to NIST, this program can accurately calculate properties such as heat capacity, enthalpy, entropy, and Gibbs free energy of reactions as a function of temperature.

Research into the basic science behind calibrations and measurements is an important part of CSTL's work. One example is research being done on the molecular dynamics of clusters of silicon atoms. The research shows what happens when clusters collide and grow, and how they may be incorporated into a film layer causing the formation of surface defects on semiconductor microchips. Semerjian describes how CSTL research has shown that there might be a critical silicon cluster size that facilitates even flow and deposition during manufacturing. Smaller clusters just stay in the gas flow and don't become part of the deposit, while large clusters impact the surface and cause defects.

CSTL also is at the forefront of biotechnology research such as the development of DNA profiling. This method for identifying the unique patterns within human genes is being used by about 200 state, federal, commercial, and research labs. Law enforcement agencies rely on it to match DNA samples from crimes, and the Defense Department is putting into place a DNA dog-tag program so there will be no more unknown soldiers.

CSTL has developed two standard reference materials that biotechnology labs can use to make sure their DNA profiles are accurate and precise. One assesses the accuracy of the restriction fragment length polymorphism method of DNA profiling, and the other checks accuracy of the polymerase chain reaction method.

International agreements—such as the Montreal Protocol on Substances That Deplete the Ozone Layer, which restricted use of chlorofluorocarbons, and recent trade agreements—have increased the international importance of standards. "We use all of our technology to establish complementary measurements with other nations," Semerjian says. "This is because as regulatory barriers to trade are going down, the technical barriers are becoming more important. Conformity assessment, for example, takes on a lot of importance."

Products sold between nations increasingly have to have compatible technologies. When a U.S. company makes a device that is to be used in Spain, the Spanish buyers have to know that that instrument meets their national performance standards. Semerjian says this kind of conformity assessment is ongoing work. "There hasn't always been mutual recognition between European accreditation and testing organizations and the U.S." he says. "This is a major issue. Conformity agreements affect trade agreements and export situations. European countries, for example, may have much more stringent standards and requirements than does the U.S. in some areas. Unless we can provide our companies with the capability to meet these requirements, we put our companies at a significant disadvantage."

NIST keeps up with the needs of industry, both national and international, by being in constant touch with its customers. "Last [month], we held a U.S.-Italy bilateral seminar where we covered all kinds of things," Semerjian says. "We have had our counterparts from the Netherlands here from Delft. We have people here from Dow Chemical now, talking to our staff." Over the past several months, CSTL has held a variety of conferences and workshops. They include workshops on industrial applications of computational chemistry, chemical analysis of automobile exhaust, NIST traceable gas standards, reverse materials engineering, and an American Society for Testing & Materials workshop on biotechnology.

The chemistry laboratory also participates in a number of ongoing NIST educational and fellowship programs. Among these are the American Chemical Society's Project SEED for economically disadvantaged high school students, college internships sponsored by the Department of Commerce, and a number of fellowship opportunities and graduate research positions sponsored by the National Science Foundation and by CSTL itself.

Industry has worked very closely with CSTL over the years. In addition to holding numerous conferences to discuss what different industries need in the way of references, company scientists frequently work on projects at NIST facilities. CRADAs are negotiated to cover costs and the assignment of NIST staff to work with the visiting scientists. NIST is also promoting a new industry fellow program, in which NIST staffers work as visiting researchers in an industrial laboratory, typically for three to 12 months. Not only do these programs improve government-industry cooperation, but they help NIST identify technical trends and opportunities.

Semerjian points out that CSTL had about 260 guest researchers in fiscal 1995. "These people come from industry and from academia, from overseas, and from other federal laboratories. They are people who can benefit from our capabilities," Semerjian says. "Some standards-setting organizations have hired full-time personnel to work here and provide a liaison with their organization." The College of American Pathologists, for example, has had an employee working at CSTL for more than 15 years on developing standards and methods for testing materials such as serum triglycerides and cholesterol.

It's obvious that chemical activities are a big part of NIST and that they are expanding. Construction of a new building to house chemical labs is just about ready to begin to replace the 30-year-old facility that now houses most of CSTL. Expanding international conformity requirements and increasing regulations at home will keep scientists in the new building as busy as they are in the old one. ☐

Mrs. MORELLA. Thank you. Your written statement in its entirety, which is very effective, will be part of the record.

Thank you.

Dr. Warner?

STATEMENT OF DR. ISIAH WARNER, IMMEDIATE PAST CHAIR, NATIONAL RESEARCH COUNCIL BOARD ON ASSESSMENT OF NIST PROGRAMS, PANEL FOR CHEMICAL SCIENCE AND TECHNOLOGY

Dr. WARNER. Thank you, Madam Chairwoman.

Madam Chairwoman, and Members of the Subcommittee, you have my more comprehensive report. What I will give you here is a concise version of that report.

I am pleased and privileged to address you today as the Immediate Past Chair of the National Research Council's Panel for Chemical Science and Technology, one of seven panels of the Board on Assessment of NIST Programs.

I am currently Chair of the Department of Chemistry and Phillip W. West Professor of Analytical Environmental Chemistry at Louisiana State University, and I have previously held positions at Emory University in Atlanta, and Texas A&M University.

I have been a member of this Panel from 1992 to 1995, and served as Chair in 1995. The Panel currently has 14 members. Six of those members are from industry, six from academe, and two from government laboratories.

In its 1995 review, the Panel found that the programs currently underway in the Chemical Science and Technology Laboratory are generally of the highest technical quality. These programs tend to focus on the technical strengths of the laboratory and address critical national needs.

For example, the laboratory plays a leading role in the development of biosensor technology. Currently, the industrial applications of this technology are limited because available devices lack sensitivity and are chemically and thermally unstable.

As another example, the laboratory's efforts in atmospheric chemistry have an extensive impact on setting environmental standards and on establishing methods to determine the sources of carbon in the atmosphere.

The laboratory also develops surface, analytical, and characterization techniques that are of vital importance to the semiconductor manufacturing industry.

One major activity of the laboratory is the determination of chemical and physical properties of substances in mixtures of scientific and industrial relevance.

In physical chemistry, chemicokinetics and thermodynamics NIST experimental measurements and data evaluation methods are unique in the world and present a key national asset.

The availability of such data has undoubtedly resulted in enormous cost savings and productivity gains for those industries that rely on chemical, biochemical, or materials' processing.

In fiscal year 1994, technical staff of the laboratory authored nearly 600 publications, certified nearly 160 Standard Reference Materials, and maintained 17 data bases related to standards and metrology.

The high quality of the technical programs and the number and quality of publications suggest that the laboratory is making a significant contribution to the development of the technology infrastructure required by U.S. industry.

However, the laboratory does face some challenges.

For example, the laboratory is in danger of losing critical expertise in areas where NIST has unique capabilities and responsibilities.

In some cases, expertise currently resides in one individual who may be nearing retirement. Some major projects are carried out by nonpermanent staff members. These scientists are well qualified and the research does not appear to suffer from their lack of permanent status, but the long-term effects of such personnel policies are uncertain.

There are other areas not focused on by the laboratory that could greatly benefit industry. For example, the laboratory's biotechnology thrust does not include activity in the area of biomaterials or bioremediation.

Both of these technologies are of great industrial importance.

Also, given the increasingly widespread use of process models by the chemical, energy, and materials' processing industries, the need for evaluative data continues to grow. However, the laboratory's current efforts are not sufficient to meet the growing demand.

Despite these challenges, overall the Panel has found the laboratory to be well managed, staff morale high, and the quality and relevance of its programs very good.

Thank you.

[The prepared statement of Dr. Warner follows:]

Testimony by Dr. Isiah M. Warner, Chair
National Research Council
Panel for Chemical Sciences and Technology
to the hearing on

"Oversight Review of Research Laboratory Programs at the
National Institute of Standards and Technology"

Held by the
Subcommittee on Technology, Committee on Science
U.S. House of Representatives
May 2, 1996

Ms. Chairwoman and Members of the Subcommittee:

I am pleased and privileged to address you today as the immediate past Chair of the National Research Council's Panel for Chemical Science and Technology, one of seven panels of the Board on Assessment of National Institute of Standards and Technology (NIST) Programs. I am a Professor of Analytical and Environmental Chemistry at Louisiana State University, and have previously held positions at Emory University, and Texas A&M. I have been a member of the Panel for Chemical Science and Technology from 1992 to 1995, and served as Chair in 1995. The Panel currently has fourteen members representing a variety of experiences and expertise in chemistry and chemical engineering. Six of those members are from industry, six from academe, and two from government laboratories.

In its 1995 review, the panel found that the programs currently under way in the Chemical Science and Technology Laboratory are generally of the highest technical quality. These programs tend to focus on the technical strengths of the laboratory and address critical national needs

For example, the laboratory plays a leading role in the development of biosensor technology. Currently, the industrial applications of this technology are limited because available devices lack sensitivity and are chemically and thermally unstable. This technology shows great promise, however, and NIST efforts focus on improving the sensitivity, reliability, and stability of biosensor devices. As another example, the laboratory's efforts in atmospheric chemistry have an extensive impact on setting environmental standards and on establishing methods to determine the sources of carbon in the atmosphere. NIST is developing an understanding of atmospheric processes that will be used to determine emission standards for a variety of industries The laboratory also develops surface analytical and characterization techniques that are of vital importance to industry, since surface science underlies many of the critical technologies employed by the semiconductor manufacturing industry.

One major activity of the laboratory is the determination of chemical and physical properties of substances and mixtures of scientific and industrial relevance. These databases represent world standards in terms of the quality of the information they contain. In physical chemistry, chemical kinetics, and thermodynamics, NIST experimental measurements and data evaluation methods are unique in the world and represent a key national asset. The availability of such data has undoubtedly resulted in enormous cost savings and productivity gains for those industries that rely on chemical, biochemical, or materials processing. As an example of their usefulness, the NIST mass spectrum database has been incorporated directly into commercial mass spectrometers which are used in many sectors, including health care.

The level and effectiveness of the current impact on industry of laboratory programs can be measured by the quantity and relevance of research on measurement science and the quantity and quality of standards and reference data made available to industry. In fiscal year 1994, technical staff of the laboratory authored nearly 600 publications, certified nearly 160 Standard Reference Materials, and maintained 17 databases related to standards and metrology. The high quality of the technical programs and the number and quality of publications suggest that the laboratory is making a significant contribution to the development of the technical infrastructure required by U.S. industry. Recent efforts include research on the properties of alternative refrigerants for the refrigeration and air-conditioning industry, research on the properties of hydrocarbons and hydrocarbon mixtures for the energy industry, and development and application of vacuum standards for the aerospace and semiconductor industries. These activities have been carried out in close association with industry, and those industrial relationships have helped to ensure the success of and maximize the impact of the research activity.

The laboratory does face some challenges. For example, the laboratory is in danger of losing critical expertise in areas where NIST is recognized as having unique capabilities and responsibilities. In some cases, expertise currently resides in one individual who may be nearing retirement. In other cases, the laboratory has husbanded its scarce resources in an effective way by making use of guest researchers to fill voids in its skill base. Some major projects are carried out by nonpermanent staff members. These scientists are well qualified and the research does not appear to suffer from their lack of permanent status, but the long-term effects of such personnel policies are uncertain.

There are other areas not focused on by the laboratory that could greatly benefit industry. For example, the laboratory's biotechnology thrust does not include activity in the area of biomaterials, substances produced by genetically engineered plants or micro-organisms, or bioremediation, the use of biological organisms to clean up hazardous materials. Both of these technologies are of great industrial importance. Also, given the increasingly widespread use of process models by the chemical, energy, and materials processing industries, the need for evaluated data continues to grow. However, the laboratory's current efforts are not sufficient to meet the growing demand. Given the importance of these databases, greater attention also needs to be devoted to the electronic dissemination of this material.

Despite these challenges, overall the panel has found the laboratory to be well-managed, its staff morale high, and the quality and relevance of its programs very good

Fiscal Year 1995 Assessment of the
Chemical Science and Technology Laboratory
by the
Pane for Chemical Science and Technology

Panel Members

Isiah M. Warner, Louisiana State University, *Chair*
Kenneth O. MacFadden, W.R. Grace & Co., *Vice Chair*
John L. Anderson, Carnegie Mellon University
Joseph D. Andrade, University of Utah
Ramon M. Barnes, University of Massachusetts
Paulette Clancy, Cornell University
Anthony M. Dean, Exxon Research and Engineering Co.
David A. Dixon, Du Pont Central Research and Development Experimental Station
Robert R. Dorsch, Du Pont Central Research and Development Experimental Station
H. Frederick Dylla, Continuous Electron Beam Accelerator Facility
Steven M. George, University of Colorado
Lou Ann Heimbrook, AT&T Bell Laboratories
Lynn W. Jelinski, Cornell University
Douglas E. Leng, Dow Chemical Company
Ichiro Shinkai, Merck Research Laboratories

Invited Participants

Kathleen C. Taylor, General Motors Research and Development Center (Member at Large, Board on Assessment of NIST Programs)

Submitted for the panel by its Chair, Isiah M. Warner, this assessment of the fiscal year 1995 activities of the Chemical Science and Technology Laboratory is based on a site visit by the panel on March 22-23, 1995, and on the annual report of the laboratory.

LABORATORY OVERVIEW

Mission

The mission of the Chemical Science and Technology Laboratory (CSTL) as presented to the panel by its director is to maintain a world-class research laboratory recognized by the nation as the primary source for chemical, biomolecular, and chemical engineering measurements, data, models, and reference standards required to enhance U.S. industrial competitiveness.

Resources

Fiscal year 1994 funding for the Chemical Science and Technology Laboratory included $27.8 million from NIST Scientific and Technical Research and Services (STRS) funds, $14.9 million from other agency (OA) sources, $1.6 million from the Advanced Technology Program, and $6.3 million from fees charged for calibrations, Standard Reference Materials (SRMs), standard reference data, and other reimbursable services.

The Priority-Setting Process

The priorities of the Chemical Science and Technology Laboratory are expressed through a set of four goals enunciated by the laboratory director. The goals are (1) to establish the Chemical Science and Technology Laboratory as the pinnacle of the traceability structure for measurements in chemistry, chemical engineering, and biotechnology; (2) to assure that U.S. industry has access to accurate and reliable data, models, and predictive algorithms; (3) to anticipate and address the next generation measurement needs of the nation; and (4) to foster the development and implementation of advanced process technologies.

To continuously evaluate and refine the goals of the organization and to establish programs that effectively meet those goals, the laboratory maintains a strategic plan that serves to shape and inform all of its activities. The process of formulating the strategic plan is an ongoing one in which all members of the laboratory management directly participate. Great care is taken to ensure that all laboratory staff members understand the plan and the strategy to implement it. Staff are encouraged to contribute to all phases of the planning process.

Assessment of Priorities and the Priority-Setting Process

The priorities established by the laboratory as expressed in the *Strategic Plan of the Chemical Science and Technology Laboratory* are appropriate and well implemented. The programs undertaken by the laboratory are focused on the laboratory mission and address the needs of U.S. industry.

The laboratory has done an excellent job of establishing an effective process for setting priorities and clearly enunciating that process. Both the criteria used in allocating resources and the management process that ensures programs are focused on the laboratory mission are well documented in the strategic plan. The strategic plan could benefit, however, from the establishment of milestones for individual projects and from the inclusion of benchmarks with respect to other organizations involved in similar activities.

The division does a good job of incorporating industrial input gathered from Cooperative Research and Development Agreements (CRADAs), workshops, and other less formal interactions into the strategic plan and the programs required for its implementation. The complexity of modern chemical technologies, the uncertainties inherent in an environment where new technology is rapidly evolving, and the strict restraints imposed by global competition make it difficult for any organization to choose its strategic investments wisely and to anticipate new avenues of technical development. Continued close contact with the relevant industries will be a key factor in enabling the laboratory to choose those few critical problems that it can address most effectively.

Although the laboratory encourages the participation of all laboratory staff in the priority-setting process, the goal of achieving meaningful involvement and commitment from the staff has not been fully realized. In some cases, the staff members do not feel that their input is valued by laboratory management.

Assessment of Technical Programs

The programs currently under way in the laboratory are generally of the highest technical quality New initiatives continue to focus on the strengths of the laboratory and address critical national needs. The laboratory has made significant improvements in its equipment stock, and plans are under way for a general upgrade of the facilities through the construction of a new building.

The laboratory maintains 17 databases, 88 percent of the total number of databases maintained by NIST. The databases address key industry needs and represent world standards in terms of the quality of the information they contain. They are routinely accessed in the process of addressing problems of national importance, such as studying the effect of pollutants on the earth's atmosphere or improving industrial processes used in the chemical, material, and biological product industries. Continued effort will be required to maintain the databases as well as to provide improved access to them.

The laboratory is in danger of losing critical expertise in areas where NIST is recognized as having unique capabilities and responsibilities. These areas cover fundamental thermochemical properties: pH and conductivity measurements, calorimetry, thermometry, and pressure measurements It is not clear how the laboratory plans to maintain expertise in these areas.

Assessment of Impact on Industry

The level and effectiveness of the current impact on industry of laboratory programs can be measured by the quantity and relevance of research on measurement science and the quantity and quality of standards and reference data made available to industry. The technical staff of the laboratory authored nearly 600 publications, certified nearly 160 SRMs, and maintained 17 databases related to standards and metrology. The Standard Reference Materials and the databases represent key components of U.S. manufacturing infrastructure. The high quality of the technical programs and the number and quality of publications suggest that the laboratory is making a significant contribution to the development of the technical infrastructure required by U.S. industry.

The laboratory has signed a number of CRADAs with industrial partners. There is currently no mechanism within the laboratory or within NIST as a whole to evaluate a CRADA once it is completed to judge its value to NIST and its industrial partner. Such a process might be useful to better gauge the impact of CRADA activity

The Industry Fellows Program is too new to be assessed in terms of its effectiveness, but the program, as conceived, should yield direct benefit to NIST and to industry by deepening the level of interaction between the two. Based on interviews with laboratory personnel, the implementation of the Industry Fellows Program could be improved by promoting the advantages of the program within the organization, especially those advantages that accrue to individuals who participate in the program.

Recommendations

The following are the panel's recommendations for the Chemical Science and Technology Laboratory as a whole.

- The panel recommends that means be developed to preserve critical expertise in areas where NIST is recognized as having unique capabilities and responsibilities and where expertise currently resides in one individual who may be nearing retirement. Specifically, the panel recommends preserving expertise in the area of fundamental thermochemical measurements: pH, conductivity, calorimetry, thermometry, and pressure measurements.

- The Chemical Science and Technology Laboratory management should make every effort to encourage the meaningful involvement and full commitment of the laboratory staff in the strategic planning process. Communication with the staff might be facilitated by introducing a frequent one-page memorandum or electronic mail message from the director updating all employees on current activities and decisions.

- Although the laboratory is clearly an internationally recognized institution, the panel recommends that benchmarks be established for comparison to other national and international laboratories in both government and industry. This benchmarking process should be implemented by current staff with minimal impact on technical programs.

- Although laboratory personnel garner many of the internal NIST and government awards, the panel recommends that the laboratory management be more aggressive in nominating laboratory personnel for national and international awards. Such awards would further enhance the stature of the laboratory.

Chemical Science and Technology Laboratory Response to Fiscal Year 1994 Recommendation

The panel is generally satisfied with the actions taken and explanations provided by the laboratory in response to concerns and recommendations voiced in the fiscal year 1994 assessment report. The primary recommendation from the 1994 assessment and the laboratory's response to it is given below.

1994 Panel Recommendation: "The Chemical Science and Technology Laboratory should continue its emphasis on the strategic planning process. . . . Benchmarking of costs and program progress, as well as expanded analyses of how CSTL programs compare with nationally and internationally based work, must be regularly performed" (p. 72).

Laboratory's Response: The laboratory has just completed a full revision of its strategic plan and intends to distribute it to the panel at this year's meeting for comment and review. NIST has established a highly structured process for planning and measuring results. CSTL has been a prime mover in this process.

DIVISIONAL ASSESSMENTS

Biotechnology Division

Mission

The mission of the Biotechnology Division is to advance the commercialization of biotechnology by promoting further development of the technological infrastructure of the biotechnology community and developing reliable measurement techniques and data to enable U.S. industry to quickly and economically produce biochemical products with appropriate quality control.

Resources

Fiscal year 1994 funding for the Biotechnology Division included $6.2 million from STRS funds, $0.8 million from OA sources, and $0.6 million from other sources. The division staff includes 47 full-time equivalents, of whom 42 are technical professionals or other technical staff.

The Priority-Setting Process

The division maintains a close association with the Biotechnology Industry Organization (BIO). Together with BIO, the division is currently developing a technology roadmap for the future development of the biotechnology industry.

Assessment of Priorities and the Priority-Setting Process

The Biotechnology Division has done a superb job in selecting and organizing its programs and is well positioned to meet the needs of the rapidly growing biotechnology industry. The division has been diligent in seeking numerous external inputs into its priority-setting activities. As a result, it has made well-informed and appropriate program choices. The division has been effective in moving forward into new areas of research, such as bioprocess engineering, and has achieved notable success in redirecting the research activities of key staff members as needed. The division has established a comprehensive and effective means of involving group leaders and staff in the development of programs and priorities. The degree to which staff and managers agree with and actively further the programs and priorities of the division is remarkable and is reflective of the extent to which their involvement has been solicited.

Assessment of Technical Programs

The panel was impressed with the quality, quantity, and impact of the work being performed by the Biotechnology Division. A new level of excellence has been achieved, and morale is high. Much of this progress is due to the outstanding leadership, vision, enthusiasm, and dedication of the division chief and the individual group leaders.

The division has established itself as the world leader in high-quality, high-reliability, and high-accuracy DNA-based analysis and diagnostics. The division makes use of the latest advances in analytical chemistry and advanced molecular biology techniques to address metrology issues critical to the further development of advanced DNA probe and sequencing techniques, advanced DNA-based methods of human identity testing, new methods of DNA repair, and DNA-based methods of environmental monitoring.

The division is particularly strong in the area of structural biology and protein engineering. Expertise in protein crystallography, molecular biology, biophysical characterization, computational chemistry, and numerical modeling is combined in an integrative approach to protein engineering. Team projects move seamlessly through these technical areas, as exemplified by the successful creation of a new enzyme specifically engineered for detergent applications. The division could benefit, however, by acquiring state-of-the-art nuclear magnetic resonance capability and integrating it into the structural biology and protein engineering effort.

The bioprocess engineering effort has been reorganized under new leadership and is now working effectively toward harnessing the electron transfer capabilities of P450 enzymes for use in chemical manufacturing processes.

The division continues to play a leading role in the development of biosensor technology. Currently, the industrial applications of this technology are limited because available devices lack sensitivity and are chemically and thermally unstable. This technology shows great promise, however, and the division's efforts are focused on improving the sensitivity, reliability, and stability of biosensor devices.

Assessment of Impact on Industry

In general, the division is creative, effective, and efficient in addressing the needs of the rapidly growing biotechnology industry. To continue to meet those needs, however, the division must continue to grow. Staff, equipment, and space allocated to the division all must be substantially increased if the division is to keep up with the demands of this burgeoning industry.

The division currently has no activity in the area of biomaterials, substances produced by genetically engineered plants or micro-organisms, or bioremediation, the use of biological organisms to clean up hazardous materials. Both of these technologies are of great industrial importance, and the division ought to acquire the relevant expertise in order to address the needs of these segments of the biotechnology industry.

Recommendations

The following are the panel's recommendations for the Biotechnology Division.

- There is a growing national need for biotechnology infrastructural technology and standards. To meet this need, the Biotechnology Division will need to grow substantially in the years ahead. The division must plan for aggressive growth and must secure the additional staff, space, and resources required to fuel that growth.

- The division should acquire a 600 MHz nuclear magnetic resonance spectrometer and integrate this capability into the structural biology and protein engineering effort.

- Insofar as resources and staff limitations allow, the division should acquire expertise in biomaterials and bioremediation, and active research in these two areas should be planned and implemented.

Biotechnology Division Responses to Fiscal Year 1994 Recommendations

The primary 1994 recommendations for the Biotechnology Division, quoted from the fiscal year 1994 assessment, and the division's response to them are given below

1994 Panel Recommendation: "The division should initiate programs in biomaterials and bioremediation. Important new products in these areas and alternative waste treatment will need both the research advances and standards that NIST is uniquely qualified to provide" (p. 72).
Division Response: The Biotechnology Division has developed a program initiative on biomimetic materials for consideration in the fiscal year 1997 budget process. In addition, CSTL has initiated a program in biocatalysis, which includes biodegradation, and has developed a proposal for expansion in this area as well.

1994 Panel Recommendation: "The division and the laboratory should consider the international community in their assessments of needs and opportunities Self-assessment should include comparisons with comparable groups and activities in other advanced nations" (p. 77).
Division Response: Many division and laboratory scientists serve on international committees, chair international meetings, and have significant international scientific collaborations.

Chemical Kinetics and Thermodynamics Division

Mission

The Chemical Kinetics and Thermodynamics Division serves as the primary agent for the transfer of chemical information to the U.S technological community through the production of chemical data and databases needed by U.S. industry To this end, the division provides measurements of key kinetic and thermodynamic quantities, compiles and evaluates data, produces and disseminates chemical databases, carries out theoretical calculations, and develops predictive schemes for chemical data

Resources

Fiscal year 1994 funding for the Chemical Kinetics and Thermodynamics Division included \$3.1 million from STRS funds, \$2.0 million from OA sources, and \$0.1 million from other sources. The division staff includes 30 full-time equivalents, of whom 29 are technical professionals or other technical staff.

The Priority-Setting Process

The programs of the division, including both experimental and data evaluation activities, are driven by one or more of the strategic thrusts of the Chemical Science and Technology Laboratory. In particular, division activities address environmental technology and concerns, fundamental measurement technology, industrial processes, and health care technology. Some projects, such as those dealing with analytical chemistry, computational chemistry, and chemical database development, may have applications in several, or all, of these thrust areas. The single most important thrust of the programs of the Chemical Kinetics and Thermodynamics Division is environmental research. Programs in atmospheric chemistry and kinetics, combustion kinetics, solar energy storage technology, and environmental process technology are all oriented toward this major thrust area.

Assessment of Priorities and the Priority-Setting Process

The priorities of the Chemical Kinetics and Thermodynamics Division and the structure of its programs are appropriate and consistent with its mission. The division has husbanded its scarce resources in an effective way by making use of guest researchers to fill voids in its skill base. The important work that was carried out on the division's data programs over the last few years would not have been possible without the assistance of guest researchers. This program has had the added benefit of maintaining the competence of Eastern European scientists until such time as economic conditions in their home countries improve and they can return there to pursue their scientific interests. The guest worker strategy is laudable in times of fiscal restraint but may not be healthy for the division over the long term.

Assessment of Technical Programs

The quality of the research pursued within the Chemical Kinetics and Thermodynamics Division is extremely good The staff morale is high; they are interested in and excited about their research. The data programs are progressing and clearly set world-class standards for thermochemical and kinetic databases. In the past, the staff have been concerned that the importance of the data programs was not fully appreciated by NIST management. This situation has been remedied, and the change has had a significant positive impact on the morale of the division staff.

The division is the primary resource within NIST for expertise in physical chemistry as related to chemical kinetics and thermodynamics The combination of experimental measurements and data evaluation methods is unique in the world and represents a key national asset. The division provides many of the printed and electronic databases, as well as important experimental measurements, that are used in solving problems of national importance. The measurements and databases are used, for example, in climate modeling and in the design of improved chemical, biochemical, and material processing. The data programs have a high value, and significant improvement has been made in the organic thermochemistry, ion-molecule thermochemistry, and mass spectrum databases.

The division is in danger of losing critical mass in some areas that are central to its mission For example, there has been attrition in the area of ion-molecule kinetics measurements although NIST has played a leadership role in this area. This attrition will have a negative long-term impact on the data programs as expertise in evaluating these measurements is lost.

Otherwise, the division maintains an outstanding program in fundamental kinetic measurements which are crucial to the understanding of basic chemical interactions and which, in turn, contribute to the understanding of atmospheric chemistry, combustion chemistry, and reactive plasma processes used in semiconductor manufacturing and chemical processing. Development of new kinetics databases continues with research on gas phase kinetics, condensed phase radical reactions, and the new proton affinity database.

The division has initiated a small, but not insignificant, effort in the application of computational chemistry as a tool for the evaluation of thermochemical databases. Given current trends within the chemical processing industry, this technology is likely to have widespread application especially as hardware and software improve. The division is in the position to assume a leadership role in this area, but more resources are required Specifically, the division would need to acquire greater expertise in the area of electronic structure theory.

Assessment of Impact on Industry

The impact on industry of the activities of the Chemical Kinetics and Thermodynamics Division is significant. The division is the primary source of reliable, high-quality thermodynamic and kinetic data. The availability of such data has undoubtedly resulted in enormous cost savings and productivity gains for those industries that rely on chemical, biochemical, or materials processing Those firms that manufacture mass spectrometers, for example, have incorporated the mass spectrum database directly into their measurement systems. Commercial mass spectrometers that include the NIST database are used in all business sectors, including health care.

Many of the databases maintained by the division have been converted into electronic form which serves to increase the availability of the data to end-users. Further work is needed to improve the cross-platform compatibility of the electronic databases Compatibility for use on UNIX-based workstations would be especially useful.

Given the increasingly widespread use of process models by the chemical, energy, and materials processing industries, the need for evaluated data continues to grow. The division has responded to this need by adding an evaluative component to key databases and by providing improved estimation methods. The division's current efforts are not sufficient to meet the growing demand, however.

Recommendations

The following are the panel's recommendations for the Chemical Kinetics and Thermodynamics Division.

- The need for evaluated data continues to grow, and the Chemical Kinetics and Thermodynamics Division's efforts in this area must grow accordingly if it is to meet this critical need. The panel recommends that the division make the case to NIST management for more resources in this area.

- There is a possibility that, as a result of normal attrition, the unique capabilities of the division in the area of classical thermodynamic and kinetic measurements may be lost. Graduate students at research universities are no longer being trained in these disciplines. Therefore, it is up to the division to see that this knowledge is preserved and passed on to the next generation of scientists.

- The division needs additional resources to expand its effort in the application of computational chemistry as a tool for the evaluation of thermochemical databases. Specifically, the panel recommends the appointment of a senior scientist with well-developed expertise in electronic structure theory.

- Given the importance of the kinetic and thermodynamic databases produced by the division, greater attention needs to be devoted to the electronic dissemination of this material, especially since the printed versions significantly lag behind the electronic releases. Software should be compatible with a broader range of platforms, particularly the UNIX-based workstations widely used in the industrial community.

Chemical Kinetics and Thermodynamics Division Responses to Fiscal Year 1994 Recommendations

The primary 1994 recommendations for the Chemical Kinetics and Thermodynamics Division, quoted from the fiscal year 1994 assessment, and the division's response to them are given below.

1994 Panel Recommendation: "The several computational chemistry efforts under way in CSTL, although having specific individual goals, need clearly delineated milestones and must be tied to laboratory strategic goals. . . . Appointment of a senior investigator would add credibility to this effort and provide the technical leadership to advance this initiative" (p. 80).
Division Response: Computational efforts in the division this year have been focused on developing tools to predict thermochemical and kinetic data and on providing theoretical

validation for evaluated data. In the absence of sufficient funding to bring in a new investigator, the critical mass of the activity has been increased by the involvement of another staff member with a strong background in computational chemistry.

1994 Panel Recommendation: "The Reference Data Centers Group's current compilation of kinetic data should be expanded significantly to include evaluation components in all areas. Such an effort is critical if NIST is to play a pivotal role in providing the information required for nonexperts to perform reliable process modeling calculations" (p. 81).
Division Response: Current directions indicate that funding will be available to expand kinetics data evaluation efforts into new areas, such as data for plasma processing. Until then, one additional employee is being reassigned to work on evaluation of kinetics data. At the current staffing levels, complete coverage of all kinetics data is not feasible.

Analytical Chemistry Division

Mission

As the nation's reference laboratory for chemical metrology and compositional analysis, the mission of the Analytical Chemistry Division is to conduct research concerning the qualitative and quantitative determination of chemical composition, develop and maintain state-of-the-art chemical analysis capabilities; provide measurement quality assurance through reference materials, data, and services; and provide a basis for U.S. chemical measurement traceability and international comparability. The division provides these infrastructural capabilities to address concerns including U.S. industrial competitiveness, environmental quality, and public health and safety. The Analytical Chemistry Division provides these resources for U.S. industry, government agencies, and academic institutions, as well as the international scientific community.

Resources

The Inorganic and Organic Analytical Research Divisions were not officially combined into the Analytical Chemistry Division until after the 1994 fiscal year ended. Fiscal year 1994 funding for the Inorganic and Organic Analytical Research Divisions included $7.2 million from STRS funds, $3.0 million from OA sources, and $2.9 million from other sources. The staff of the two divisions consisted of 86 full-time equivalents, of whom 79 were technical professionals or other technical staff.

The Priority-Setting Process

The Inorganic and Organic Analytical Research Divisions were combined into the Analytical Chemistry Division early in the 1995 fiscal year. The new division will continue NIST's leadership role in advanced analytical method research and development critical to the needs of U.S. industry and in support of other government agencies, especially in the areas of quality assurance, environmental technologies, clinical chemistry, and advanced materials manufacturing. The division will also play a leadership role in the critical evaluation, development, and transfer of chemical metrology to facilitate international trade and provide the analytical measurement for cost/benefit analysis for business and environmental applications, as well as quality systems documentation. The programs of the division are being evaluated in terms of the overall strategic plan of the Chemical Science and Technology Laboratory and in terms of the goals stated above.

Assessment of Priorities and the Priority-Setting Process

The major research activities of the division which include research on chemical sensing technology, laboratory automation technology and standards, analytical separation science, and nuclear analytical methods are directed toward the environmental, forensic, and health care thrusts of the laboratory as a whole. The division's mission is wide ranging and ambitious, and available staff are spread thinly across program areas. Some major projects are carried out by nonpermanent staff members. These scientists are well qualified, however, and the research does not appear to suffer from their lack of permanent status.

Assessment of Technical Programs

The panel is impressed with the quality of the research programs pursued within the division. The consolidation of the Inorganic Analytical Research Division and the Organic Analytical Research Division into the Analytic Chemistry Division was a very positive step. The programs of the division are well focused on the division's mission.

A high level of competence has been developed in both instrumental and radiochemical neutron activation analysis, prompt gamma activation analysis, and neutron depth profiling. The division has pioneered the use of neutron beams as analytical probes with both prompt gamma activation analysis and neutron depth profiling. The long-term program to explore and develop the analytical applications of focused beams of cold neutrons progressed significantly this year with the design of a new neutron lens.

The division's efforts in the area of classical and electroanalytical chemistry are productive, and many of these activities result in important standards and calibration techniques of great relevance to industry. The future of these efforts is unsettled as the division's chief electrochemist is scheduled to retire soon and a replacement has not yet been identified.

The division's efforts to expand elemental, isotopic, and molecular speciation should be emphasized and strengthened. The current research on methyl mercury is a good example. The research is sound, but the intensity of the effort is inadequate to meet the future demand for Standard Reference Materials with speciation information for use in environmental and health sciences. The goals of the division in this area ought to include the provision of certified values of total as well as speciated forms of environmentally and biologically significant metals, for example, in all future SRMs and in as many existing SRMs as possible. As new technology is developed to expand the quantitative speciation capability, new and existing SRMs should be recertified for the new speciated forms.

The division's efforts in analytical mass spectroscopy continue to make significant contributions to the development of improved isotope ratio measurements, isotope dilution analysis, and tracer studies and to the evaluation of fundamental constants The division's capacity to perform high-resolution measurements would be enhanced by the acquisition of a high-resolution inductively coupled plasma emission mass spectrometer. Enhanced capability would facilitate the extension of detection limits to levels lower than those currently attainable so that environmental, biological, and semiconductor material samples could be measured with improved accuracy and precision

Assessment of Impact on Industry

Overall, the division's contributions to industry are impressive. A high level of interaction with industrial and academic scientists is apparent from the large number of guest researchers, research associates, and joint publications

The separation science group has developed new separation technologies and has provided several new Standard Reference Materials for environmental contaminants Newly developed techniques, such as the separation of chiral molecules using supercritical fluid extraction and the characterization of biomolecules using new methods of mass spectroscopy, promise to yield a significant positive impact on industry in the future.

Through the Consortium on Automated Analytical Laboratory Systems, the division participates in the development of common, precompetitive concepts that will benefit industry by lowering component development costs, reducing the time required to develop new components, and providing design criteria for the development of reusable components

Recommendations

The following are the panel's recommendations for the Analytical Chemistry Division.

- The Analytical Chemistry Division should evaluate existing and proposed Standard Reference Materials (SRMs) for the feasibility of elemental, isotopic, and compound speciation. As the division's speciation capability improves, certified values of speciated forms should be included in new and existing SRMs

- The imminent retirement of the division's chief electrochemist will seriously impede the division's efforts in classical and electroanalytical chemistry unless the skills and expertise represented by that individual are replaced. The division should give serious attention to identifying and recruiting a replacement electrochemist.

- The division should acquire, if possible, a high-resolution inductively coupled plasma emission mass spectrometer. The instrument should have multicollector capability for simultaneous isotope measurement

Analytical Chemistry Division Responses to Fiscal Year 1994 Recommendations

The Inorganic and Organic Analytical Research Divisions were combined during fiscal year 1994 into the Analytical Chemistry Division. The recommendations from the fiscal year 1994 assessment and division responses that follow reflect the prior organizational structure.

1994 Panel Recommendation: "The division needs new research on plasmas used in analysis, more emphasis on molecular spectroscopy, and a rejuvenation of its programs in lasers and electroanalytical chemistry. More external interactions and connections to the CSTL thrust areas are required" (p. 73).
Division Response: Effective in early fiscal year 1995, the functions of the Inorganic Analytical Research Division and the Organic Analytical Research Division were combined into the Analytical Chemistry Division. The new division's mission is to conduct research concerning the qualitative and quantitative determination of chemical composition; develop and maintain state-of-the-art chemical analysis capabilities; provide measurement quality assurance through reference materials, data, and services; and provide a basis for U.S. chemical measurement traceability and international comparability. The resources within the division will be used to carry out this mission and will be consistent with the major thrusts of CSTL. The division's efforts in molecular spectroscopy have been expanded, including various infrared spectroscopies in collaboration with the automotive industry to develop new low emissions detection technologies. New efforts are being initiated in the area of near infrared (NIR) sensing and standardization. Efforts concerning the use of lasers to investigate plasmas are ongoing. Though plans are not totally firm, the division is seriously considering reincarnating the old Electrochemistry Group as the Classical Chemical Analysis Group. Critical mass efforts would be maintained in macrochemical characterization, spectrometric standards, pH and conductivity standards, and high-purity reagents. Electroanalytical capabilities will be maintained and utilized within the mission of this group.

1994 Panel Recommendation: "The division should establish competency in analytical and separation methods involving supercritical fluids. The division's aging magnetic sector mass spectrometer should be replaced" (p. 73).
Division Response: Supercritical fluid extraction, separation, and processing is an area that the division has identified for growth. A new double-focusing magnetic sector mass spectrometer was ordered to replace two older magnetic sector instruments.

1994 Panel Recommendation: "The division should develop an expanded program in molecular spectroscopy to complement its solid programs in atomic spectroscopy. Also needed is an expansion into molecular speciation, which will involve atomic and molecular spectroscopy or separation methods, or both" (p. 84).
Division Response: Partly as a result of the merger of the Inorganic and Organic Analytical Research Divisions, the division's efforts in molecular spectroscopy have been expanded and diversified. Several efforts from the Organic Analytical Research Division involving various infrared spectroscopies are being focused on collaborations with the automotive industry to develop new low emissions detection technologies. New efforts are being initiated in the area of NIR sensing and standardization.

A new collaborative effort between the Separation Science Group and the Nuclear Methods Group is being focused on the development and critical evaluation of independent methods for the determination of methyl mercury in fish

Process Measurements Division

Mission

The Process Measurements Division is the nation's reference laboratory for the development of sensing and measurement standards and technology, process models, and key chemical engineering data required for understanding, optimization, and control of process streams with special emphasis on high-technology materials, environmental technologies, and advanced cryogenic and refrigeration systems. The division develops and maintains the nation's reference standards and services for measurement of air speed, fluid flow rate, humidity, liquid density and volume, temperature, and transient pressure. The division provides these services to U.S. industry, government agencies, and the scientific community to enhance the nation's productivity and competitiveness; to assure equity in trade; and to improve public health, safety, and environmental quality.

Resources

Fiscal year 1994 funding for the Process Measurements Division included $5.3 million from STRS funds, $1.5 million from OA sources, and $1.3 million from other sources. The staff of the division consists of 64 full-time equivalents, of whom 59 are technical professionals or other technical staff.

The Priority-Setting Process

During fiscal year 1994, the Process Measurements Division was organized into six groups: Fluid Flow, High-Temperature Processes, Reacting Flows, Process Sensing, Thermometry, and Fluid Systems (located in Boulder). The thrust areas that have been identified are flow measurement techniques; calibrations and computational fluid dynamics simulations for industry; measurement and modeling of reactors for toxic waste treatment and other high-temperature processes; new routes to materials synthesis via experimental and theoretical investigations; chemical sensors, from self-assembled monolayers and thin film and array-structured semiconductors; and combined experimental and computational research into heat and mass transfer in multicomponent, multiphase systems.

Assessment of Priorities and the Priority-Setting Process

The selection of projects, the technical merit of those projects, and the leadership within the division are all excellent. The division's choice to focus on the measurement of temperature, pressure, density, and flow as the core technologies relative to its mission is clearly appropriate. The increased emphasis on flow is particularly appropriate given that this is the most difficult and least developed of the core technologies noted above. The division's new programs, such as new research into semiconductor processing, have been initiated with a level of resources and managerial attention sufficient to assure success.

Assessment of Technical Programs

The technical programs of the division are excellent and contribute significantly to the enhancement of U.S. industrial competitiveness.

The division made significant progress in the development of new techniques to measure fluid flow. A factor-of-four improvement in flow measurement accuracy was demonstrated.

The division shares responsibility for the development of new thermal measurement techniques with the Physics Laboratory, which focuses on radiometric techniques, and the Thermophysics Division of the Chemical Science and Technology Laboratory, which focuses on acoustic resonance techniques. Communication between these different organizations was improved, and NIST's thermometry efforts are better coordinated than they have been in the past. The Thermometry Group within the Process Measurements Division continues to produce impressive results.

The Process Sensing Group demonstrated a multisensor array capable of identifying numerous gaseous species. This technology will have broad application in the area of monitoring gaseous emissions. The self-aligned monolayer project pursued within this group is ultimately aimed at biosensing and analysis through protein capture. Both the Thin Film Multisensor Array project and the Self-Aligned Monolayer project hold great promise for future industrial applications. However, these projects have long time horizons, and annual reviews may be necessary to gauge their progress.

Several research groups within the division experienced a change in leadership and, although the leadership transitions appear to have gone smoothly, the new group leaders could benefit from a management training program, much like those established in industrial laboratories, which would facilitate the rapid improvement of their managerial skills.

Assessment of Impact on Industry

The core technologies pursued by the Process Measurements Division are of fundamental importance to maintaining the competitiveness of U.S. industry. The chemical processing industry is exposed to ever-increasing competitive challenges in the global marketplace. As pressure to reduce costs continues, research activities have been reduced and the industry has become increasingly reliant on NIST for basic research and metrology services. The current activities of the division are well positioned to address the needs of industry, and new programs initiated within the division hold great promise for meeting future needs.

Recommendations

The following are the panel's recommendations for the Process Measurements Division.

- The panel suggests that the Process Measurements Division conduct annual reviews of those projects with long time horizons, such as the Multisensor Array and the Self-Aligned Monolayer projects pursued by the Process Sensing Group, in order to gauge their progress and determine whether the skills and resources available are adequate to assure ultimate success.
- The panel recommends that the division define and implement a training program for new group leaders so that they may more rapidly and effectively improve their skills in managing diverse groups of scientists and scientific projects.

Process Measurements Division Responses to Fiscal Year 1994 Recommendations

The primary 1994 recommendations for the Process Measurements Division, quoted from the fiscal year 1994 assessment, and the division's response to them are given below.

1994 Panel Recommendation: "The division should develop a program leading to replacement of mechanical measurement devices by electronic or optical standards in U.S. industry and augment it with capabilities in all measurement areas to make CSTL a major international leader in measurement technology. . . ." (p. 73).
Division Response: The Process Measurements Division initiated programs in the last 2 years which have the character suggested by the panel. In the area of temperature measurements, the division initiated a new research program to greatly enhance the thermodynamic accuracy of the temperature scale by incorporating the best in acoustic and radiometric measurement technology into its realization of the scale. In humidity measurements, the division has a new program to use optical measurement technology to extend the range of its ability to measure water vapor to parts per billion levels of sensitivity. Finally, in the area of flow measurements, it initiated a study of the use of modern, acoustically based flow meters to maintain flow measurement standards.

1994 Panel Recommendation: "NIST capabilities in each of the fundamental measurement areas of temperature, fluid flow, pressure, and humidity should be benchmarked against the capabilities of leading international laboratories and a strategy adopted (or maintained) to keep them among the world's best. Process measurement capability is at the heart of NIST's purpose and should not be compromised as NIST adapts to meet other national needs" (p. 90).
Division Response: A fundamental operating requirement for all these measurement areas is to benchmark the division's facilities with those around the world in other national laboratories. The

program in temperature standards has a long history in these types of benchmarking activities covering the realization of the scale as well as thermometric devices such as thermocouples.

Surface and Microanalysis Science Division

Mission

The Surface and Microanalysis Science Division serves as the nation's reference laboratory to determine the physics and chemistry of surfaces, particles, and materials and their interactions with photons, electrons, and ions on the micro- to nanoscale by advancing measurement science and by developing measurement methods, standards, reference data, and models. The division uses its capabilities to address problems of national concern in chemistry, materials, electronics, and atmospheric chemistry including source apportionment. Basic information is developed to enhance U.S. industry's productivity and competitiveness, assure equity in trade, and improve public health and safety and environmental quality. The division provides these capabilities for industry, government agencies, and the scientific community.

Resources

Fiscal year 1994 funding for the Surface and Microanalysis Science Division included \$3.8 million from STRS funds, \$4.6 million from OA sources, and \$0.8 million from other sources. The division staff includes 44 full-time equivalents, of whom 41 are technical professionals or other technical staff.

The Priority-Setting Process

The emphasis in the division's activities is placed on performing fundamental and applied measurement research; providing data and standards, including software; and developing theories that are needed for accurately measuring chemical composition and dynamic processes that occur on surfaces and in microstructures. The data and standards produced by the division help to establish the relationship between chemical composition and processing, devices, and material properties and provide the basis for advances in related technologies such as catalysis, advanced microelectronic processing, and materials science.

Assessment of Priorities and the Priority-Setting Process

The programs of the division are appropriately aligned with the mission of the division and the overall mission of the laboratory and NIST. The management, both at the division level and at the group level, continues to provide leadership that fosters excellence in the scientific and technical work of the division.

The Microanalysis Group was split into two groups, the Analytical Microscopy Group and the Microanalysis Research Group, in order to address the metrology needs of industry in a more focused manner. The restructuring appears to have gone smoothly, and the two new groups are operating effectively.

Assessment of Technical Programs

In general, the technical programs of the division are excellent. The Atmospheric Chemistry Group generates important results in the area of chemical metrology. The efforts of this group have an extensive impact on setting environmental standards and on establishing methods to determine the sources of carbon in the atmosphere. The group is developing an understanding of atmospheric processes that will be used to determine emission standards for a variety of industries.

The Microanalysis Science Group has a strong technical program and functions effectively as a team. The group is known for its work on experimental electron microscopy and image analysis and quantification. The group has identified problems with the widely used standardless x-ray line analysis technique, which could have a significant impact on the way this technique is applied. The recent acquisition of an environmental scanning electron microscope is an excellent addition to the resources of the group. The group acquired an atomic force microscope (AFM) as recommended by the 1994 Assessment Panel, and this new equipment will complement the group's capability to perform scanning scattering microscopy. However, the new capacity to perform atomic force microscopy needs to be more forcefully directed toward addressing real-world industrial problems. Currently, the AFM is being used only as a research tool. It is not part of a program to develop new applications and enhanced capability, although that is the stated goal of the division in this area. Increased interaction with industry, especially in the area of semiconductor processing and fabrication, is required to establish a more focused and coherent AFM Program.

The division conducts world-class research in the area of laser-surface interactions. New nonlinear optical techniques were successfully applied to the problem of probing buried interfaces, and new studies of radical surface chemistry were initiated. A new titanium-sapphire laser system was acquired that should greatly enhance the effectiveness of the division's research in this area. The addition of a new investigator to the Surface Dynamical Processes Group, with new expertise and perspective, would serve to further enhance the effectiveness of this research.

Atmospheric chemistry research conducted within the division continues to be relevant to the evolving national need. Efforts in isotope ratio mass spectrometry are excellent. The ozone measurement calibration services address a critical national and international need. The effectiveness of the technical programs in atmospheric chemistry is based on a team approach to problem solving. This team has been led by a highly effective group leader who has since been promoted to the status of NIST fellow. The future success of these efforts will depend on the development of new leadership within the atmospheric chemistry group. The group needs independent principal investigators to lead the research. Such skill can either be acquired by developing the leadership skills of existing researchers within the Atmospheric Chemistry Group or by recruiting new staff.

The division is in need of some new equipment in the areas of field emission Auger and near-field scanning optical microscopy and additional enhancement to existing secondary ion mass spectroscopy equipment. The division may want to consider acquiring a focused ion beam device for sample preparation.

Assessment of Impact on Industry

The division develops surface analytical and characterization techniques that are of vital importance to industry. Surface science underlies many of the critical technologies employed by the semiconductor manufacturing industry, and the understanding of atmospheric processes being developed by the atmospheric research group will be used to set emission standards for a variety of industries.

The impact on industry of the division's activities can best be measured by the degree to which the division's services are sought by industry and the effectiveness with which NIST-developed technology is transferred to industry. These measures should be incorporated into the review process used by the division to assess the progress of individuals researchers and research groups.

Recommendations

The following are the panel's recommendations for the Surface and Microanalysis Science Division.

- The Atomic Force Microscopy Program needs to develop further ties to industry and create a more focused, coherent, and industrially relevant program.
- The Atmospheric Chemistry Group is in need of one or more independent principal investigators. These can be developed from among the existing staff, or new candidates can be identified and recruited.
- The Surface Dynamical Processes Group is highly effective, but its effectiveness would be further enhanced by the addition of another principal investigator with skills and expertise outside of the current activities of the group.

Surface and Microanalysis Science Division Responses to Fiscal Year 1994 Recommendations

The primary 1994 recommendations for the Surface and Microanalysis Science Division, from the fiscal year 1994 assessment, and the division's response to them are given below.

1994 Panel Recommendation: "The division should take initiatives in semiconductor processing and nanostructure materials and scanning tunneling and atomic force microscopies. SRMs should

be developed for International Organization for Standardization 9000 series guidelines (ISO 9000) for materials testing" (p. 73).
Division Response: The division has taken definitive steps in advancing and maintaining its active involvement in semiconductor processing and nanostructured materials through several programs in collaboration with the Electronics and Electrical Engineering Laboratory and the Material Science and Engineering Laboratory. The division recently acquired an AFM to determine surface roughness and defect production in semiconductor materials and correlate the measurements with those obtained with the scanning scattering microscope developed in the division. The division is also developing the near-field scanned microscopy and spectroscopy capabilities for the chemical identification of species with nanometer spatial resolution. This effort is part of an initiative proposal to develop a national facility for chemical and materials microanalysis. The division has initiated efforts that will help industry in ISO 9000 quality requirements by providing standards for calibration and traceability, protocols for accurate measurements, and interactive round-robin exercises to test the standards, protocols, and collaborators.

Thermophysics Division

Mission

The Thermophysics Division is the nation's reference laboratory for measurements, standards, data, and models related to process separations, to the thermophysical properties of fluids and fluid mixtures, and to pressure, vacuum, partial pressure, and leak rate. The division develops and maintains state-of-the-art experimental, theoretical, and modeling capabilities and provides technical research and services to enhance the productivity and competitiveness of U.S. industry and to assist U.S. industry, other government agencies, and academia in solving problems of national importance.

Resources

Fiscal year 1994 funding for the Thermophysics Division included $4.4 million from STRS funds, $3.0 million from OA sources, and $0.5 million from other sources. The division staff includes 57 full-time equivalents, of whom 51 are technical professionals or other technical staff.

The Priority-Setting Process

The division organizes its programs and projects in such a way as to best meet the mission of the division and of the Chemical Science and Technology Laboratory as a whole. The priorities of the division are set in accordance with the procedures outlined in the *Strategic Plan of the Chemical Science and Technology Laboratory.*

Assessment of Priorities and the Priority-Setting Process

The division has followed through on last year's panel recommendation to complete a strategic planning exercise and has begun to implement the decisions that followed from that exercise. The resulting strategic plan identifies both existing programs that are to be strengthened as well as new program areas to be initiated. Two of the new initiatives, development of a new high-temperature thermometry standard and the development of optical methods to measure low gas density, have received funding from the highly competitive NIST competence program. Both projects are components of larger collaborations within NIST. The Thermometry project is a collaboration with the Process Measurements Division, and the Optical Methods Density Measurement project is part of the NIST Semiconductor Metrology initiative. The collaborative nature of these projects serves to effectively leverage the resources of the division and its collaborative partners.

The division has made notable progress on a number of the management issues that were enumerated by the 1994 Assessment Panel. With regard to staffing problems, the number of unfilled positions was reduced from six to three and the full-time staff was supplemented by the creative use of university collaborations that are not affected by NIST hiring ceilings. Collaborations were established at Princeton University, the University of Delaware, the College of William and Mary, the University of Colorado, and the University of Idaho. Such collaborations, involving visiting faculty, postdoctoral researchers, and graduate students, were encouraged by last year's panel in view of the relatively low level of such activities in the Thermophysics Division. The division is to be commended for the number of collaborations it initiated over the past year.

Despite additions to the staff, the division remains short staffed relative to its program commitments. The situation at the management level was exacerbated by the loss of two key supervisors during the past year. The remaining management personnel are overworked. Some of the administrative workload could possibly be distributed among qualified members of the research staff.

The redirection of activities in fluids research in order to rationalize the division between the Fluid Science Group in Gaithersburg, which focuses on fundamental fluid science leading toward standards development, and the Fluids Group in Boulder, which engages in fundamental property measurements of pure fluids and mixtures and also maintains a complementary modeling effort, has proven to be successful. The activities of the Fluid Science Group in Gaithersburg complement the activities of the Pressure and Vacuum Groups also located in Gaithersburg.

The division receives more than 42 percent of its total funds from OA sources. Much of this support funds essential measurements that the other agencies require and cannot procure from other sources. In general, the OA-funded activities are compatible with the mission of the division, and arbitrary reductions in the use of OA support may not be in the best interests of the division. However, given the fact that near-term budget trends may reduce the ability of other federal agencies to fund work at NIST, the division should be in a position to decrease its reliance on OA funding.

Assessment of Technical Programs

The overall quality of the division's research activities is excellent The Vacuum Group made significant progress in focusing its activities on research with direct benefit to the semiconductor processing industry, namely, development of calibrated water leaks, development of improved calibration protocols for residual gas analyzers, and development of optical methods of measuring the partial pressure of gases. The latter project was awarded NIST competence funding, and all of the efforts mentioned above are part of the NIST-wide National Semiconductor initiative.

The Vacuum Group is engaged in exciting and potentially useful work in laser photo ionization. In addition to the original work involving multiphoton ionization, the group is also exploring optical ring-down techniques which could be useful for accurate partial pressure measurements of water and other industrially significant species at pressures greater than 10^{-4} torr.

The general problem of the inability to reliably calibrate residual gas analyzers (RGAs) despite their widespread use in the semiconductor industry is an important area of research for the Vacuum Group. However, the problem requires more resources than are available within the group. The group should outline a general strategy with respect to the study of RGA calibration and then restrict its efforts to specific problems that can be effectively addressed with the group's expertise and resources The group has made a step in this direction with its project to design a generic calibration system that may be used on many of the RGAs currently in use in industry.

The Vacuum Group's development of calibration systems for gas flow measurements at low flow rates (10^{-8} sccm to 1 sccm) represents an important contribution to fundamental vacuum technology. The calibration range established by the Vacuum Group overlaps the range of most leak detectors used to qualify vacuum equipment and instrumentation. The group intends to extend low flow leak calibration to higher ranges (up to 1000 sccm) which will be important for gas flow metering devices used on plasma process and chemical vapor deposition equipment.

The Pressure Group provides industry with calibration services for high-pressure piston gauges from 1 to 300 bar. Research activities include extension of the division's calibration capability pressures up to 5000 bar and development of a new primary gauge at 1 bar that may replace existing primary standards based on mercury manometers. Currently, the group leader is on leave from the group and is working in the NIST Director's Office. The group leader's absence appears to have had a negative impact on the scope of the group's activities. For example, the calibration services provided by the Pressure Group are carried out primarily by technicians, and funding for these activities comes from fees for delivered calibration services and industry contracts. Considering the present subcritical size of the Pressure Group, it may make sense to combine this group with the Vacuum Group.

The Fluid Science Group is concerned with determining the thermophysical properties of fluids and fluid mixtures using a combination of experimental, theory, and simulation techniques. There are clear signs of the evolution of a new thrust toward standards development within this group. Basic studies are being conducted in four areas: acoustic-based flow measurements, use of new radio frequency techniques for the estimation of thermophysical properties such as viscosity, development of a potential new pressure standard using dielectric measurements, and development of a new thermometry scale. The creativity and innovation represented by this research were recognized this year by the promotion of the group leader to the status of NIST fellow and the award of an American Physical Society Fellowship.

In general, the division's research in the area of the thermophysical properties of fluids and fluid mixtures is outstanding. Researchers in this area are enthusiastic, top-quality individuals who have chosen projects at the cutting edge of research in their discipline. For example, ambitious research is under way to study the properties of polar mixtures under supercritical conditions where theoretical studies and computer modeling will be difficult. As exemplified above with the research activities of the Fluid Science Group, the division continues to develop new experimental techniques to measure thermophysical properties such as transport properties, dielectric properties, and thermodynamic states. A dwindling number of universities and research laboratories remain active in thermophysical property estimation. The Thermophysics Division is recognized as the world leader in this research, and its activities in this area become increasingly more important as other research institutions exit the field.

The division is engaged in innovative research involving atomic-level computer simulations. The choice of projects, tight binding studies of semiconductor materials and classical studies of the properties of polarizable water, has great potential for yielding valuable information and should be of general interest to the scientific community. Numerical simulation is widely recognized as a vital component of research often providing insight that cannot be obtained by experiment. The panel is concerned, however, that current staffing levels may be inadequate to carry out this activity. The division's expertise in this area resides in one senior NIST fellow. The panel would like to see the addition of a new staff member in this area if possible.

The focus of the Fluids Group located on the Boulder campus is currently on three areas: separations, properties of alternative refrigerants, and fluid property modeling. Progress in all three areas has been substantial during the last year. The search for replacement chlorofluorocarbons is roughly at its peak, though the search for a replacement for the refrigerant R22 will continue for several more years. The quality of the experimental data and the associated modeling of the equation of state is outstanding, as evidenced by the acceptance of the NIST-developed equation of state of the refrigerant R123 as the international standard for this molecule. In the area of separations, the group is investigating the use of supercritical fluid extraction (SFE) in environmental separations. In an interesting collaboration between this group and the new Working Fluids Group, alternative refrigerants are being investigated as potential supercritical fluid solvents for SFE.

The Cryogenic Technologies Group was established this past year and has found an appropriate place within the division. The project to develop cryocoolers, advanced refrigerators capable of maintaining temperatures lower than 120 K, is highly innovative and has attracted considerable attention from the National Aeronautics and Space Administration, Department of Defense, and Department of Energy. A Cooperative Research and Development Agreement has been established with Cryenco to develop new coolers for use in the storage of liquefied gases; this research could have a strong impact on the design and operation of fleet vehicles in the next 10 years. The Cryogenics Technologies Group makes good use of the knowledge of fluid properties available from other research groups within the division.

Assessment of Impact on Industry

The Thermophysics Division continues to engage in and develop effective interactions with industry, primarily through its database and standards development activities, calibration services, and CRADAs. Of the 17 projects that NIST highlighted in its 1994 assessment of the industrial impact, three were projects carried out in the Thermophysics Division: (1) research on the properties of alternative refrigerants for the refrigeration and air-conditioning industry, (2) research on the properties of hydrocarbons and hydrocarbon mixtures for the energy industry, and (3) development and application of vacuum standards for the aerospace and semiconductor industries. All three activities listed above have been carried out in close association with industry, and those industrial relationships have helped to ensure the success of and maximize the impact of the research activity.

Recommendations

The following are the panel's recommendations for the Thermophysics Division.

- The staff level of the Thermophysics Division is judged to be low relative to the number of existing and planned projects The panel recommends the addition of two new members to the scientific staff, if possible. one senior member for the pressure group and a junior staff member for the atomic-level computer simulation effort. The administrative load of the properties of fluids group should be distributed among qualified staff.

- The near-term budget trends for the other federal agencies that support division activities do not look promising, and the division should develop a contingency plan to cover the potential reduction in OA funds over the next 5 years.

Thermophysics Division Response to 1994 Recommendations

The primary 1994 recommendation for the Thermophysics Division, quoted from the fiscal year 1994 assessment and the division's response to it is given below.

1994 Panel Recommendation: "The division needs to develop a more complete strategic plan. Innovative efforts should be made to increase university relations and establish advanced modeling of mixture property behavior" (p. 73).
Division Response: The division had completed strategic plans for all groups as part of CSTL's overall strategic planning process. As an integral part of these efforts, the division prioritized new and existing research directions and made several hiring decisions accordingly. The division has established several new links with university research groups. Some of these involve research conducted at universities, and some involve graduate students or postdoctoral researchers from universities working with NIST.

Mrs. MORELLA. Thank you, Dr. Warner.

We will now turn to Dr. Colwell, whom I must advise the audience is also a constituent of mine and a good friend.

Dr. COLWELL. Very proudly so.

Mrs. MORELLA. Thank you. And very proudly do I have you before the committee. Thank you.

Dr. COLWELL. Thank you.

STATEMENT OF DR. RITA COLWELL, PRESIDENT, UNIVERSITY OF MARYLAND BIOTECHNOLOGY INSTITUTE, UNIVERSITY OF MARYLAND

Dr. COLWELL. Chairwoman Morella and Congressman Brown, it is an honor to testify today.

I should identify myself as President of the University of Maryland Biotechnology Institute, of which one component is the Center for Advanced Research in Biotechnology, which is a partner with the Chemical Science and Technology Laboratory.

I should also point out, can't resist it, that I am the immediate past president of the American Association for the Advancement of Science, and I notice that one of our covers of *Science Magazine* was on the posterboard a moment ago, and also that Congressman Brown is an honorary member of the AAAS, and we are very proud of that.

I apologize for not having turned in written testimony. I just returned a few days ago from heading a delegation of Asian and Pacific science and tech leaders to Beijing, China, where we met with Premiere Li Peng to discuss partnerships in science and technology in that region.

What I would like to talk about today is the extraordinary partnership that exists between NIST and the Center for Advanced Research in Biotech, or CARB.

This is a true Federal/State/University/industry partnership. It is a national laboratory that has partnered very effectively with the University, but also has partnered with the County, and with the State, and with industry in a very, very workable interaction.

Let me say a little bit about the importance of biotechnology because this is an industry that did not even exist in 1970. Really, about 1973 when the cloning of genes was first initiated.

In that 25, or 23 to 25 years, over 1000 companies have been formed in the United States, 1013 at the last count by the Ernst accounting firm, and is capitalized at $48 billion. It is expected—right now it employs over 100,000 people, more than the largest pharmaceutical company in the United States, Merc—and it is expected to employ nearly a million people well into the 21st Century.

So biotech, the cloning of a gene, really is akin to the discovery of the printing press, the steam engine, the computer, the splitting of the atom. So the cloning of a gene has launched us into an entirely new era in a new industry.

We have to invest in biotech over the next several decades because we are on the leading edge of this revolution that will change fundamentally the way products are conceived and manufactured in many sectors of the U.S. economy, all the way, as you have heard, from health care to chemical manufacturing.

NIST's traditional role in measurements, standards, data, and models are critical for the commercialization of biotechnology, and we have to at the same time be prepared to recognize and respond to the needs of industry.

Let me just give a couple of examples that I think are very telling.

In DNA technologies and standards development, DNA profiling, the methods and the standards are being developed to accurately characterize DNA profiles for forensic and other uses—some very notorious trials, that I won't mention—which depend on DNA standards.

A Standard Reference Material for quality control and standardization of forensic DNA testing was completed in August 1992. The research continued and led to the next generation of DNA profiling standards based on the PCR, the polymerase chain reaction technology, and this standard was completed last June.

New methods are being developed for rapid DNA extraction, amplification, separation, and computer imaging. There is work progressing toward a mitochondrial DNA standard which is one of the—mitochondrial DNA sequencing is the basis of determining evolution and relationship of let's say humans with our predecessors in the evolutionary chain.

Another area is in DNA sequencing. Specific reference materials and development of technical expertise are required in the area of DNA-related technologies that are essential for DNA genomic research.

This is an area that is exploding. DNA damage and repair methods at the molecular level using GCMS. These are techniques that will find their way into medicine very soon.

Let me, because I want to be brief, and in the interest of time, let me just say a couple of areas in the future where we are working together with CARB, CARB and NIST, is in the bioinformatics research to respond to industry's need in the use of information technology to guide and accelerate biotechnology development.

In the area of health care, NIST's effort in DNA technology has already had an impact in forensics and human identity communities and has to be expanded to the health needs' community, and we are working together on that.

Finally, an important role in the evolution of the technology of assessing, evaluating, and validating algorithms in the commercial and public domain software.

Let me just point out one area where the NIST/CARB interaction has led to the development of a biological macro molecule crystallization data base. It is now on the World Wide Web. It was one of the first NIST data bases to be put on the Web with a true searching capability.

There is an awful lot more I could say, because I think that this interaction of the—it is a seamless web. It is an interwoven fabric of NIST scientists and the University of Maryland scientists and industry scientists working together at CARB on the fundamental developments in biotechnology and I think is a paradigm for University/National Laboratory partnerships.

With that, I thank you for the opportunity to speak.

Mrs. MORELLA. I thank you all very much. It was very informative.

I guess I would start off with Dr. Semerjian. I very much value the fact that you have a glossary of acronyms, since you recognize that this is an acronyms society here, a list of what they all stand for. Someone could be talking, and you might, a paragraph later, never understand a word they said because they are using all the acronyms that they just assume you do know.

I guess I might start off by mentioning an acronym. Much of the CSTL work in Standard Reference Materials' measurements and models and databases is highly valued by the traditional chemical process industries.

In recent years it seems to be a branching out to support newer industries such as biotechnology, health care, and environmental industries. Some may see these activities as falling under the jurisdiction of other agencies—again, NIH, but also now EPA, NOAA.

How does the NIST role in these activities differ from that that is performed by those other agencies? What makes it so special?

Dr. SEMERJIAN. Sure. Dr. Gebbie already addressed, you know, some aspects of that in terms of our interactions with NIH, but the situation is similar with the other agencies in the sense that their mission, in the case of NIH, is medical research to find the effect of treatments, et cetera, and they indeed rely on NIST to provide the measurement technology and the measurement standards to assure measurement quality—that is, the accuracy and the reliability.

We have a very similar situation with the EPA. They are a regulatory agency. We are a measurement standards' oriented organization. Our mission, again, is to make sure that the decisions that are being made, the measurements that are being made, either by industry or by EPA, are accurate and traceable to national standard measurements.

We have similar relationships with NCI, CDC, where we have Quality Assurance programs. So they really all come to us to make sure that the quality of their measurements is maintained high, and that their decisions that they are making are based on good science and good measurements.

Mrs. MORELLA. So you are absolutely imperative. I mean, they cannot do anything without NIST because you set the standards.

Dr. SEMERJIAN. We tend to think so.

[Laughter.]

Dr. COLWELL. Of course.

Mrs. MORELLA. Dr. Warner, you mentioned something that has always interested me. That is, federal personnel. That is why I also serve on the Civil Service Committee, because I represent so many federal employees in the work force, and recruiting and retaining is critically important.

In your testimony you talk about the laboratory facing challenges which then renders it vulnerable to inadequacies in some areas, I suppose by just tying people and just not being able to recruit, and scarce resources.

I wanted to ask you how you think we should address it.

Secondly, in the technology transfer bill that became law that I had introduced, we made permanent that personnel program that

NIST has that is so special. Why doesn't that help? I mean, what can we do?

I thought you had enough of the instruments to be able to avert that.

Dr. WARNER. As I mentioned in my testimony, in one particular area that is of concern there is expertise that is maintained in some cases, particularly in CSTL, by one individual. If that individual were to retire, that expertise disappears altogether.

That is a concern.

In other areas of course it is good that we hire outside personnel in NIST and bring in new expertise, but then much of this new expertise may exist with non-permanent staff. Without the capability of converting that nonpermanent staff into a permanent person, again if that person leaves CSTL then the problem is created that the expertise also leaves CSTL.

Dr. SEMERJIAN. May I address some of that?

Mrs. MORELLA. Yes, Dr. Semerjian.

Dr. SEMERJIAN. Of course the issue is not a matter of tools. Certainly the personnel system we have now at NIST goes a long way in terms of giving us the tools to manage our human resources.

The issue is really more of financial resources in the sense that when we know somebody is going to retire, let's say, over a year—usually we know these things ahead of time—the problem is, what we would like to do of course is be able to hire somebody else ahead of this retirement so that the know-how is transferred to the incoming person. But that means that we have additional resources to hire that additional person for that period of time.

So it is really a matter of resources. What we find is that our services are in such demand that we tend to increase our reach, so to speak, to many more areas than we actually are capable to, and that is why we tend to spread our capabilities thinner than we would like to see. And in some cases, indeed we are trying to look and see where we can cut back so that we can strengthen other areas so that we can focus a little more.

Mrs. MORELLA. How much time do you need to train somebody to take over?

Dr. SEMERJIAN. In some areas it would take more than a year.

Mrs. MORELLA. So in other words, what you would suggest is that you have the ability to hire somebody to also work in that function during that last year before that person leaves, or whatever, for retirement.

Dr. SEMERJIAN. That is right.

So in some cases that is not necessarily a full-time job in terms of simply learning what that person can contribute, but still you are talking about an additional person. So it is really a matter of resources and how do we set our priorities, and how do we spread our resources.

It is not an issue of having the tools——

Mrs. MORELLA. Is it not appropriate for us in Congress then to say to NIST, hey, you work this out. You know this person is going to be retiring and has these critical skills, now you recruit; bring it in. Find some way to take care of it, some way.

Dr. SEMERJIAN. And we do.

Mrs. MORELLA. And you do, but you still have those problems.

Dr. SEMERJIAN. Well, there are always—

Mrs. MORELLA. And yet we talk about these people who are looking for jobs, too. Again, they probably do not have that level of experience, but you have got to get them into the pipeline, don't you?

Dr. SEMERJIAN. We are really looking for very special kinds of people who are interested in metrology, interested in measurement science standards, and it really takes a special not only training but a special interest.

Mrs. MORELLA. You know, with the downsizing that is taking place, we are thinking of all of these so-called soft landing approaches, and maybe retraining in other parts of the Federal Government, it occurred to me. Is there a possibility that one could be—as someone who is going to be leaving another agency but who has some of that same expertise, or at least the background for it, maybe not the specific data, could be transferred there on kind of a probationary period, or something, to see if they could fit in?

Do you see what I am saying? It's a shifting. We're talking about a transfer from one federal agency to another; I frankly think transferring also from federal agencies to the private sector is a good idea, too, and I am going to be trying to work on that on a demonstration program.

But, any innovative comments you may have?

Dr. SEMERJIAN. We actually take advantage of other capabilities where we know that there are other laboratories to work on the secondary level standards, et cetera, who are in the tradition of working on measurement science, measurement standards, and we certainly look for those kind of people.

We have several examples where we have transferred people from other agencies. We really take advantage of all the tools.

Mrs. MORELLA. I hope also, Dr. Warner and Dr. Semerjian, that you let us know if there is something we can do in a specific situation or in general.

Dr. WARNER. If I could add one other comment?

Mrs. MORELLA. Yes.

Dr. WARNER. There are areas in which NIST has a very unique capability. For example, in the thermodynamics area, these are, for example, pH measurements, and conductivity measurements.

These are things that might not be considered now to be flashy research areas, but they are areas that are critical to the national needs; and NIST has the capabilities that are unique in the world.

Those are examples of areas that need to be maintained.

As Dr. Semerjian has indicated, you have to have someone with the training or interest in measurement technology. NIST sets the standards in the world in terms of measurement technology.

There are countries all over the world that are now trying to mimic what is going on in NIST. I think that is so important that we maintain that world leadership in that area.

Dr. COLWELL. If I could make a comment?

Mrs. MORELLA. Of course, Dr. Colwell.

Dr. COLWELL. You know, as we approach Federal budget exigencies and downsizing, we have to recognize that there are areas that are growing, like biotechnology. So the biotechnology division of NIST should not be cut off at the roots, if you will; that it does need to expand in informatics, and into advanced DNA technologies.

So there has to be space for growth, especially in this very critical area where we have the leadership but it is getting more fragile by the hour. So that we have to maintain our leadership.

Mrs. MORELLA. I would certainly agree with the biotechnology facet of it. We have right in our own Montgomery County, Maryland—and I don't mean to be provincial—at least 90 biotechnology companies, along with the NIH, and FDA, and HHS, and certainly NIST.

Well, I spoke to the NIST alumnae the other day. It seemed to me there were an awful lot of eager beavers there, and I do not know how you could use them, or whatever, but do not ever forget you have got some resources that might be willing to, on a voluntary basis, assist in some way.

Dr. Colwell, I remember I was at the dedication of CARB, and it is certainly a national model. Do you know of any other areas that are trying to emulate what is being done at CARB?

Dr. COLWELL. Oh, yes. As a matter of fact, I think the University of Maryland Biotech Institute, which has a new approach to things, is being replicated in other states like Connecticut and South Carolina. But I think what is more interesting is that I should point out that in a very short ten years CARB has catapulted to leadership in X-ray crystallography and structural biology. It is amongst the top three or four in the country.

So I think that is a demonstration of how you can partner very effectively excellent scientists in a national laboratory and in a university and create leadership in a very, very short time by sharing resources, human as well as the physical equipment, and so forth.

So there are two points to be made.

One is that you can optimize on both sides when you have a downsizing that is occurring financially; but on the other hand the model is being replicated. It is being—we get visitors constantly—and I must say, we get visitors from Japan.

As a matter of fact, the protein engineering laboratory in Osaka is really structured after CARB.

Mrs. MORELLA. I have a couple more questions to ask, but before I do I want to recognize the two Members who are here also, because time is of such essence.

Dr. Brown, I would like to recognize you for any questions you may have.

Mr. BROWN. Again I thank the gentlelady. I will try and be reasonably brief.

I hope that all of you recognize that the gentlelady in the Chair is one of the staunchest defenders and trumpeters of the excellence of NIST in Congress, unquestionably the strongest, and you have every reason to be very proud of her, as she is proud of you.

I envy her the position that she has in representing a District which has this great institution in it, NIST, as well as the University of Maryland and its excellent research facilities.

Of course while it is not in our jurisdiction, you have also NIH and its great research capabilities. So I think it is probably an unmatched situation in the Congress. It is a very well-matched situation to have a person of her outstanding capability representing that.

I have one——

Mrs. MORELLA. I am glad we have a record being made here.

[Laughter.]

Mr. BROWN. You may use it in your campaign.

[Laughter.]

Mr. BROWN. I have one reason to be proud. As you mentioned the development of biotechnology, one of the benefits of my seniority is that I have watched this development since its very inception; from the CLSA MAR Conference, I have been proud to know Dr. Watson who did the original research on DNA, and it is very rare that you see a totally new industry develop from scratch with the kind of impact that you have described in terms of thousands of companies, billions of dollars in revenues, some of which the U.S. Government gets a good piece of, and the number of people who are employed.

This is extremely impressive, and my memories of my service in Congress will be enriched by knowing that I was a small part of that development over a long period of time.

I have a couple of questions which I hope can be answered briefly.

Dr. Colwell, you spent some time discussing the importance of partnerships and the way that they have developed in connection with your work.

As you know, the concept of government/industry/university partnerships is not without its detractors.

We need to make clear that this is something of significance. You probably are aware that the Council on Competitiveness has issued within the last few weeks a report which extols partnership as the wave of the future, precisely the kind of things that you are doing.

Now I do not want to ask a leading question, but is it possible that there are defects in this structure, excesses that we need to examine that might otherwise threaten what is otherwise an excellent arrangement?

Is it possible that such a thing as corporate welfare, which is the way some of these partnerships are described, if it results in a sharing of costs with industry, for example, can you elaborate on that just a bit?

Dr. COLWELL. Yes. I would be delighted to.

First just let me say that we in the biotech community are extremely grateful to your extraordinary contributions over the years. We recognize it, and we thank you.

In answer to your question, I think the important point to be made is that we must recognize that the fundamental mission of the university is to educate the next generation; and that we also, as public universities, must do research for the research universities and units. We also provides service to our local communities and to the larger community of our Nation, and even the larger community of human kind.

Having said that, I think it is critical that we open up new vistas, as has been mentioned in the previous panel, to students that is beyond simply replicating professorial positions; but it is to integrate science and technology into the general community, both to increase science awareness of the public that it is science and technology that has contributed to the improved standard of living, and the continued improved standard of living.

This somehow gets lost in translation. Therefore, the more scientists, and technologists, and engineers that we train that interweave in other occupations and professions, the better we are as a country and as a common humanity.

I would say that the interactions with industry are very important—very important, because industry in undergoing downsizing has had to meet its demands to survive and to compete. And having a very strong S&T used as NIST and as the partnership with the university with industry then allows industry's resources, which have dwindled but are still there; the university's resources, which are no longer as full because state coffers are no longer full; and we have to find new ways to support our students; and then the federal laboratories.

When they are all together, I think we can partner, and we must if we are going to remain the leading nation in science and technology.

So I feel strongly about this issue.

Mr. BROWN. Well I appreciate that response very much.

Over the years, you know, there has been a feeling that, not only was there not a partnership, but there may have been actual antagonism between say industry and government; and isolation between universities and industry.

We regret that. What I am hoping is that the scientific community will take the lead in helping to remedy that because it was the scientific model of the value of intense specialization that led to some of this separation, and in fact to some of this even isolation.

It is also a criticism of government bureaucracy that we are overly focused on a narrow area and do not see outside the sphere of that area when we really should be looking at the broader system. This is one of the components of total quality management today, that you have to look at those broader systems and encourage cooperation.

Now can I hope that the scientific community will recognize its unique role? And, having created a sense of the importance of specialization, you can now create a sense of the importance of partnership.

Dr. COLWELL. I think this is happening. Part of it is just simply the times are such that there really are not other alternatives.

But, however, the model of Japan, and the model of the European Union Federation in Science and Technology, and the recognition that megaprojects will have to be funded in an international partnership, has changed sort of the attitude and the views.

In the biosciences, there was not a tradition of working with industry. In chemistry, and somewhat in physics of course there has been a tradition; but in the biosciences, this is something that is relatively new within the last two decades.

But it is clear that the opportunities of partnering with industry offer new ways of doing research, and offer new opportunities for discovery.

I think this is part of the ethos that is changing in the professorship, certainly.

The graduate students, as usual, are ahead of the professors. They are already eagerly looking for ways to have internships in industry and to explore opportunities for employment.

We may find that the faculty are being forced, as well as pulled.

Mr. BROWN. The graduate students have a definite interest in having a career ahead of them.

Dr. COLWELL. Of having a job; yes.

Mr. BROWN. May I just make a point? Chairman Walker and I both had the opportunity this week to talk to the head of the Japanese Science and Technology Agency which has broad oversight over all their programs.

He described to us fairly graphically what their plans are for a 50 percent increase over the next several years in support for basic research and advanced technology.

I pleaded with him to slow down that increase because we are going to have a 30 percent decrease, and they are going to be spending both absolutely in terms of percent of GNP, considerably more than the United States.

Dr. COLWELL. Congressman Brown, I must say that this is the most frightening aspect of science and technology, that the genuine, real dollars, U.S. dollars- match that will be spent by Japan by the year 2000 will be greater than that spent by the U.S.—that is, the projection.

I serve on the Review Committee for GMSTAC, the Marine program in Japan, and I must say that they already have a research vessel that goes deeper into the ocean; that they are already retrieving under high pressure and high temperature in some cases, and in low temperature in others, new organisms.

They are already patenting new drugs from these very deep-sea organisms.

I also have served on the MITI, the Eratinol program, which is an attempt to instill creativity into Japanese research. I must say, that is where we still have leadership in that our scientists are trained in a way to be creative and to follow their creativity.

Again, this is something that we should not stifle but we need to continue to support, to fund, and to encourage. Your words are right on target.

Mr. BROWN. I am going to encourage you to play a key role in educating Members of Congress with regard to these developments that are going to overwhelm us before very long.

Madam Chairwoman, I had some additional questions, which I will defer and put in writing, recognizing the time, and I yield back the balance of my time.

[No questions were submitted.]

Mrs. MORELLA. Thank you, Mr. Brown.

I am going to allow other Members of the Subcommittee, too, who are not here to submit any questions to you, with your approval.

I do agree with what Mr. Brown has said in terms of your being an advocate, and all of you if there areas in which you know a great deal feel that we are falling behind competitively, it is important that Members of Congress get your expertise and benefits.

I want to now recognize Dr. Ehlers. You know, he is not a Member of this Subcommittee, but I did invite him. He did know we were going to be looking at the laboratories. We already did the physics' one, but I know you are probably the only Member of Congress elected to the American Physical Society, and your name came up earlier, so I am glad that you came to correct what people had said about you—no, it was very favorable—they said there should be more physicists like Dr. Ehlers in Congress.

Dr. EHLERS. Well thank you, Madam Chairwoman.

I first of all want to associate my remarks with the generous remarks of the Ranking Member, Mr. Brown, and his comments about you and your good work on the Subcommittee, and also your good work on behalf of NIST. I certainly appreciate it.

As you said, I am not a member of this Subcommittee. I am a member of the American Physical Society, and also a member of the American Association for the Advancement of Science, and recognize my president here.

Dr. COLWELL. Thank you.

Dr. EHLERS. I congratulate you on that post.

Mrs. MORELLA. So that is why you came.

[Laughter.]

Dr. EHLERS. Yes. She is my president.

But in any event, I did want to just come and register, Madam Chairwoman, my strong support for NIST. I am quite familiar with the organization. I believe Dr. Patel earlier mentioned that I had spent a year at JILA in Boulder some years ago—in fact, almost 25 years ago now—on a visiting Fellowship, and found some very outstanding scientists working there, as well as the Bureau in Boulder.

But also I served later on on a review panel for the National Bureau of Standards, which has unfortunately been changed to NIST, and we may some day change that back. But in any event, it is an excellent organization.

They do very good science, as well as providing standards not only for the nation but for the entire world. I think it has always been a very good operation and a very good organization.

I simply wanted to go on record with that statement, indicating that they are a very important component of our Nation's research effort as well as performing the very important function of setting standards for the international scientific community.

I think it is incumbent upon us in Congress to continue our strong support for them.

Thank you, very much.

Mrs. MORELLA. I thank you, Dr. Ehlers.

I appreciate your making that statement for the record, and for those who are here. You have certainly shown you are not just a person of words but of actions when it has come to voting.

Dr. Warner?

Dr. WARNER. Madam Chairwoman, if I could also echo the comments of Dr. Colwell in regards to the amount of funds that Japan is beginning to put into science, I would like to make one comment in that regard.

As a Nation we are certainly concerned about our budget deficit, but if I am not mistaken, if you look at the budget deficit situation in Japan it is far worse than our situation, yet they continue to recognize that science is the way we should continue our funding.

In this Nation during the Sputnik era, we certainly recognize that there has been lots of spinoff from science. The current electronics revolution that we' are recognizing certainly is a spinoff of science, and therefore we expect that science will continue to produce those kinds of spinoffs and benefit the entire Nation.

Mrs. MORELLA. So it is important for competitiveness that we look to what they are doing with meager resources versus what we are able to do, and may restrain or refrain from doing.

You know, when you talked about collaboration and you mentioned DNA, Dr. Colwell, of course I mentioned Cellmark, and I recognize how important they have been in that field.

How do they relate with you? Do they have to go to you for the measurements? How does that work? What comes first?

Dr. SEMERJIAN. The measurement technologies are not—I mean, they are developed independently, but the issue is how accurate and how reliable they are. We provide the Standard Reference Materials, first of all, for the earlier technologies, and more recent the PCR technology, to make sure that those measurements are accurate.

When the questions are asked, you know, what is the probability of, you know, matching or not matching when all these statistics are thrown in the hat, those have to be based on specific information as to how well you are making that measurement and how strongly it is based on these standards.

That is really the issue. That is where we come in. Not necessarily making the measurements, or even developing the measurement technology, necessarily.

Dr. COLWELL. Could I amplify on that?

For example, Standard Reference Material 2390 is a DNA profiling standard, and it is now used for quality assurance in 80 percent of all commercial and government forensic and human identification laboratories.

So it is a material that, when they do their tests, they can make sure the experience or the test has gone correctly because the standard reacts correctly in their approach.

So it is how they can be sure that what they are measuring is right on target.

Mrs. MORELLA. I just want to ask one other question, and then the rest can be submitted, about CRADAs. CSTL has quite a few CRADAs with industrial partners, and I assume that many of these other NIST activities involve the development of intellectual property of commercial to industry.

[No additional questions were submitted.]

Mrs. MORELLA.I wonder how NIST balances the desires of the industry partner for exclusive property rights with the government's desire to diffuse this information more widely, especially when the knowledge is created with federal funds?

Dr. SEMERJIAN. That is actually very straightforward. Even in a collaboration such as CRADA, depending on who in fact has come up with the innovation. If it is a government staff, technical staff, then the patent actually belongs to the government.

If it is a result of a collaborative effort, then it is joint ownership of the invention.

Then if it is the result of the company's work, then of course it belongs to them.

In a case where we have come up with the invention, where there is an individual company that is interested in carrying that forward immediately, then we normally advertise in *Commerce Business Daily,* et cetera, the availability of that technology to make sure that other companies who may be interested in that technology become aware so that there is not an exclusive relationship established without other companies realizing that.

So I do not think we are giving away any intellectual property rights that belong to the government unnecessarily. And indeed, if it is done through an exclusive licensing arrangement, as was mentioned before, then royalties are appropriate and are collected by the government.

Mrs. MORELLA. How much royalty does NIST receive as a result of licensing NIST-generated intellectual property?

Dr. SEMERJIAN. I do not know the total number. I do not think it is very large, but we have to remember that this issue, the focus on patenting, is a relatively recent phenomenon. Therefore, we are only starting to see the result of that, since it is usually a fairly long process, not only the licensing but the commercialization, and seeing some profits from that.

So I don't think it is a large quantity at the moment.

Mrs. MORELLA. We are hoping that the new law in terms of technology transfer will provide more incentives from Federal Laboratories, private industry, in CRADA to do more of this transfer, which is another way of partnership. And I think "partnership" is that key word.

Was it in The Graduate they said plastic was the key? I think now it is partnerships. You are hearing about it in all instances.

Dr. SEMERJIAN. Could I add one thing?

Mrs. MORELLA. Yes.

Dr. SEMERJIAN. I think I wanted to mention that when Dr. Colwell was mentioning the CARB partnership, I think the secret to our success in CARB, and also in I think the other relationships, is the fact that they have been true "partnership."

At CARB, NIST does not "support" the University of Maryland, or the University of Maryland does not "support" NIST. We support each other. we work together. Our relationship is the same with industry.

We do not send out funds. They come to work with us, with their own resources. It is a true partnership. In the same situation the CRADA does, most of our partnerships that are established through CRADAs are true partnerships.

That is why I think NIST CRADAs in general have been a great success, because of our really long tradition from 1903, shortly after the inception of NBS at the time, when we started working with industry as part of our mission.

Mrs. MORELLA. Well, I think indeed it is very fertile territory in that particular, as Mr. Brown had mentioned, not only CARB with the University of Maryland, but we have got kind of the troika beautifully done with academia. Johns Hopkins has a presence there, the community college, which can do some training; high tech councils, Southern Maryland and Suburban Maryland High

Tech Councils, NIST, the other Laboratories. So it is really an idea spot for showing the rest of the country what can be done, and making sure that that does work and that we in the Federal Government have a role in it.

If you have no final comments—if any of you would like to make any final comments? Dr. Warner?

Dr. WARNER. One final comment. This is in regard to CSTL. We recognize that the data base component of NIST is a very important component. I do not know whether I included in my final—I do not recall whether I included it in my final report, but one of the important things to recognize about CSTL, is that almost 90 percent, if I am correct, of the data base work is done within CSTL.

To give you an example of the high level of competence and the regard which is held for NIST, the mass spectral data base which is generated within CSTL is incorporated directly into our industrial instrumentation without change. That is the kind of respect that is held for NIST, and those are the kinds of things that NIST has been doing in regard to industry, and to promote our continued leadership in the scientific community.

Mrs. MORELLA. You remind me of another point, Dr. Warner. We talked earlier about personnel.

Dr. WARNER. Yes.

Mrs. MORELLA. The Industry Fellows Program? Is that working?

Dr. WARNER. At the time we evaluated it, there was considerable excitement and interest in the program. But the program was fairly new, to the extent that we could not comment positively or negatively. We thought it was an excellent program, but I think it was fairly new. You may have more data, Dr. Semerjian, since our last report.

Dr. SEMERJIAN. We have two people right now from CSTL who are working in industry. At least for us, it is too early to comment on the results. I think the concept is a very good concept, and we have found surprising support from industry, which we sometimes wondered whether they would welcome scientists from the government.

That has been a very pleasant surprise for us. I think it will work.

Mrs. MORELLA. Your evaluation, when you feel you have the ample period of time to be able to evaluate, will be of great interest to us, because maybe that can be streamlined and maybe it can be proliferated in some other ways.

Dr. Colwell?

Dr. COLWELL. I would like to make just one more point about the future prospects in biotechnology for NIST. As we all know, and as you are well aware, there is a tremendous amount of sequencing being done in the human genomes, bacterial genomes, plant genomes, and the data in the powerful computing that is needed, there is a lot of searching of these sequences to pick out those genes that are involved in potential bioremediation applications, et cetera.

Again, a standardization of the algorithms and the involvement of NIST in the sequencing analyses is very critical, and it is an area that really needs to be expanded and focused on.

Mrs. MORELLA. I do not think people realize the role that NIST plays in that.

Dr. COLWELL. That is why I wanted to mention it. It really is critical to advancements in biotechnology, this burgeoning industry of the Now and the Tomorrow.

Mrs. MORELLA. Did you want to comment?

Dr. SEMERJIAN. I just wanted to thank you for your continued support for our programs. We very much appreciate your support.

Mrs. MORELLA. You do the work, I do the advertising.

[Laughter.]

Mrs. MORELLA. Dr. Semerjian, Dr. Warner, Dr. Colwell, thank you. It has been a splendid panel. Thank you, very much, for being here.

[Whereupon, at 12:10 p.m., Thursday, May 2, 1996, the hearing was adjourned.]

[The following statement was received for the record:]

APPENDIX

STATEMENT OF THE AMERICAN COLLEGE OF RADIOLOGY

BEFORE THE U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE

SUBCOMMITTEE ON TECHNOLOGY

MAY 2, 1996

The American College of Radiology (ACR) respectfully submits the following comments with respect to future funding for the National Institutes of Science and Technology (NIST). The ACR is comprised of over 30,000 physician and physicist members dedicated to the profession of radiology.

The ACR appreciates the immense challenge of the Congress and its committees to identify areas within the government that are not cost-effective. We applaud this Congress' scrutiny of existing programs to assure that the programs of the federal government provide something of value to nation. It is in this light that the ACR urges the committee to continue funding NIST programs used to assist in the accurate delivery of radiology services.

The practice of radiology has been positively influenced by the activities of NIST for many years. For medical physicists practicing in the field, these activities constitute a critical role in the accurate performance of their jobs and most critically of the medical devices they monitor. Radiation calibration measurements used in radiation oncology services to treat cancer patients and diagnostic radiology services to detect a broad range of diseases are largely based on calibration standards developed by NIST. The role of NIST to develop such calibration measurements is critical in assuring uniform standards to be followed by practitioners in the field. The absence of NIST's role in developing such standards could lead to a patchwork of state guidelines built on the determinations of individual state regulators rather than the consensus approach now achieved by the scientists at NIST.

The need to develop accurate, national standards for the calibration of devices used in the delivery of radiation oncology and diagnostic radiology services constitutes a public good that should stay squarely within the domain of the federal government. The ACR urges the subcommittee to continue to adequately fund NIST programs aimed at providing this assurance.

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